PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

"in its capacity as elected Office

Date of mailing (day/month/year) 06 July 2000 (06.07.00)	
International application No. PCT/NO99/00335	**Applicant's or agent's file reference** PAT2
International filing date (day/month/year) 05 November 1999 (05.11.99)	**Priority date** (day/month/year) 11 November 1998 (11.11.98)
Applicant BREIVIK, Jarle	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   08 June 2000 (08.06.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Manu Berrod

Telephone No · (41-22) 338 83 38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00335

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G09B 23/00 // G09B 23/26, G09B 23/24
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 3502968 A1 (KARFUNKEL, H.), 31 July 1986 (31.07.86), the whole document --	1-10
A	Derwent's abstract, No P8316 E/45, week 8245, ABSTRACT OF SU, 896675 (AS UKR PHYS MECH IN), 7 January 1982 (07.01.82), the whole document --	1-10
A	US 4846988 A (A.T. SKJELTORP), 11 July 1989 (11.07.89), the whole document --	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 March 2000	04.04.00
Name and mailing address of the International Searching Authority European Patent Office P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk Tel.+31-70)340-2040, Tx 31 651 epo nl Fax:+31-70)340-3016	Authorized officer Johan Löfstedt / MR Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00335

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	American Scientist, Volume 47, 1959, HAROLD J. MOROWITZ, "A model of reproduction" page 261 - page 263 -- ---	1-10

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/NO 99/00335

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3502968 A1	31/07/86	NONE	
US 4846988 A	11/07/89	AT 28766 T	15/08/87
		EP 0163684 A,B	11/12/85
		JP 61500567 T	27/03/86
		NO 834118 A	13/05/85
		WO 8502286 A	23/05/85

European Patent Office
Erhardtstrasse 27
D-80298 MUNICH
GERMANY

Claim 1 thus reads:

System of elements floating in a liquid which can reversibly connect to each other by magnetic forces,
c h a r a c t e r i z e d i n that the inter-elemental bindings involve magnetic materials with Curie point comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
PAT2		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/NO99/00335	05/11/1999	11/11/1998
International Patent Classification (IPC) or national classification and IPC G09B23/00		
Applicant BREIVIK, Jarle		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 1 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08/06/2000	19.02.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Watson, S Telephone No. +49 89 2399 2840

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO99/00335

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1-15	as originally filed	

Claims, No.:

2-10	as originally filed	
1	with telefax of	25/01/2001

Drawings, sheets:

1/11-11/11	as originally filed	

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-10
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-10
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-10
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:

D1: DE 35 02 968 A1 (KARFUNKEL, H.) 31 July 1986

1.1 The subject-matter of claims 1 and 10 is considered to be novel as it is not known from the available prior art to provide a system (or use of such a system) of elements floating in a liquid which can reversibly connect to each other by magnetic forces where the inter-elemental bindings involve magnetic materials with Curie points comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

1.2 The closest prior art is taken to be document D1, which shows a system of elements floating in a liquid which can reversibly connect to each other by magnetic forces (see abstract).

The subject-matter of claim 1 differs from this known system in that the inter-elemental bindings involve magnetic materials with Curie points comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

The problem to be solved by the invention is regarded as being to provide a system for simulation of reversible chemical reactions based on temperature dependent ferromagnetic interactions.

The subject-matter of claim 1 (and claim 10) is considered to be inventive as it is not known or suggested in the prior art to use the Curie point property of magnetic material to reversibly form connections.

2. Claims 2-9 are dependent on claim 1 and as such also fulfil the requirements of the PCT with regard to novelty and inventive step.

VII Certain defects in the international application

1 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2 The drawings do not fulfil the requirements of Rule 11.2 (a) PCT.

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:

BREIVIK, Jarle
Asensvingen 5C
N 0488 OSLO
NORVEGE

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Rule 71.1)

Date of mailing *(day/month/year)*	19.02.2001
Applicant's or agent's file reference: PAT2	IMPORTANT NOTIFICATION

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/NO99/00335	05/11/1999	11/11/1998

Applicant: BREIVIK, Jarle

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices) (Article 39(1)) (see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/	Authorized officer
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Schacht, I Tel.+49 89 2399-2381

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
PAT2		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/NO99/00335	05/11/1999	11/11/1998
International Patent Classification (IPC) or national classification and IPC G09B23/00		
Applicant BREIVIK, Jarle		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 5 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 1 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☐ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   - VI ☐ Certain documents cited
   - VII ☒ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08/06/2000	19.02.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Watson, S Telephone No. +49 89 2399 2840

Form PCT/IPEA/409 (cover sheet) (January 1994)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO99/00335

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
Description, pages:

1-15	as originally filed	

Claims, No.:

2-10	as originally filed	
1	with telefax of	25/01/2001

Drawings, sheets:

1/11-11/11	as originally filed	

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/NO99/00335

- ☐ the description, pages:
- ☐ the claims, Nos.:
- ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-10
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-10
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-10
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET

International application No. PCT/NO99/00335

V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Reference is made to the following document:

D1: DE 35 02 968 A1 (KARFUNKEL, H.) 31 July 1986

1.1 The subject-matter of claims 1 and 10 is considered to be novel as it is not known from the available prior art to provide a system (or use of such a system) of elements floating in a liquid which can reversibly connect to each other by magnetic forces where the inter-elemental bindings involve magnetic materials with Curie points comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

1.2 The closest prior art is taken to be document D1, which shows a system of elements floating in a liquid which can reversibly connect to each other by magnetic forces (see abstract).

The subject-matter of claim 1 differs from this known system in that the inter-elemental bindings involve magnetic materials with Curie points comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

The problem to be solved by the invention is regarded as being to provide a system for simulation of reversible chemical reactions based on temperature dependent ferromagnetic interactions.

The subject-matter of claim 1 (and claim 10) is considered to be inventive as it is not known or suggested in the prior art to use the Curie point property of magnetic material to reversibly form connections.

2. Claims 2-9 are dependent on claim 1 and as such also fulfil the requirements of the PCT with regard to novelty and inventive step.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT - SEPARATE SHEET

International application No. PCT/NO99/00335

VII Certain defects in the International application

1 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

2 The drawings do not fulfil the requirements of Rule 11.2 (a) PCT.

European Patent Office
Erhardtstrasse 27
D-80298 MUNICH
GERMANY

EPO - Munich
48
25. Jan. 2001

Claim 1 thus reads:

System of elements floating in a liquid which can reversibly connect to each other by magnetic forces,
c h a r a c t e r i z e d i n that the inter-elemental bindings involve magnetic materials with Curie point comprised by a temperature range corresponding to temperature changes in the liquid surrounding the elements.

AMENDED SHEET

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G09B 23/00 // 23/26, 23/24 — A1

(11) International Publication Number: **WO 00/28506**

(43) International Publication Date: 18 May 2000 (18.05.00)

(21) International Application Number: PCT/NO99/00335

(22) International Filing Date: 5 November 1999 (05.11.99)

(30) Priority Data:
19985267 11 November 1998 (11.11.98) NO

(71)(72) Applicant and Inventor: BREIVIK, Jarle [NO/NO]; Åsensvingen 5C, N–0488 Oslo (NO).

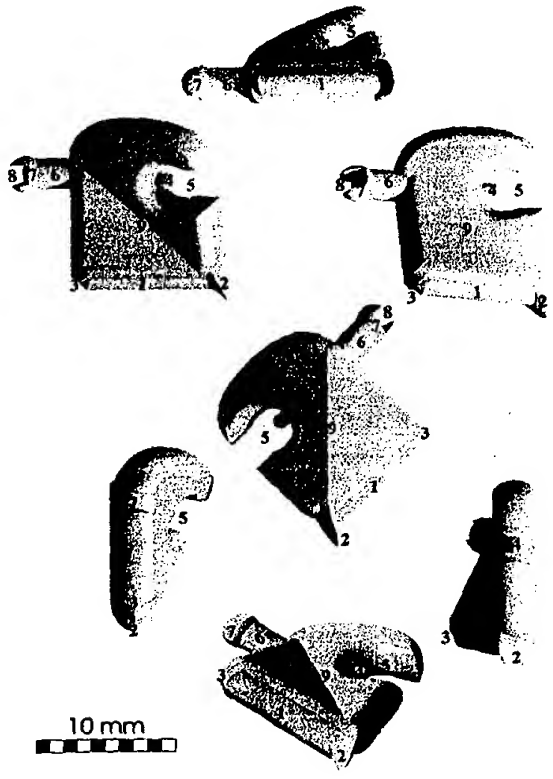
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: SIMULATION OF CHEMICAL INTERACTIONS

(57) Abstract

The present invention provides a system of elements floating in a liquid, which can bind together by temperature dependent ferromagnetic forces, wherein the elements are physically designed to provide certain characteristics to the inter–elemental bindings, and that the magnetic forces are controlled by temperature. The magnetic interactions involve materials with Curie temperatures (Tc) corresponding to temperature changes in the environment of the elements, such that specific inter–elemental attractions cease when the temperature is elevated to specific levels. The invention further comprises use of the system to simulate chemical interactions, and catalysis, wherein the bindings are manipulated by varying temperature and turbulence, and use of the system as an educational tool, an interactive game, a decoration and a tool for scientific purposes.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	**ES**	Spain	**LS**	Lesotho	**SI**	Slovenia
AM	Armenia	**FI**	Finland	**LT**	Lithuania	**SK**	Slovakia
AT	Austria	**FR**	France	**LU**	Luxembourg	**SN**	Senegal
AU	Australia	**GA**	Gabon	**LV**	Latvia	**SZ**	Swaziland
AZ	Azerbaijan	**GB**	United Kingdom	**MC**	Monaco	**TD**	Chad
BA	Bosnia and Herzegovina	**GE**	Georgia	**MD**	Republic of Moldova	**TG**	Togo
BB	Barbados	**GH**	Ghana	**MG**	Madagascar	**TJ**	Tajikistan
BE	Belgium	**GN**	Guinea	**MK**	The former Yugoslav Republic of Macedonia	**TM**	Turkmenistan
BF	Burkina Faso	**GR**	Greece			**TR**	Turkey
BG	Bulgaria	**HU**	Hungary	**ML**	Mali	**TT**	Trinidad and Tobago
BJ	Benin	**IE**	Ireland	**MN**	Mongolia	**UA**	Ukraine
BR	Brazil	**IL**	Israel	**MR**	Mauritania	**UG**	Uganda
BY	Belarus	**IS**	Iceland	**MW**	Malawi	**US**	United States of America
CA	Canada	**IT**	Italy	**MX**	Mexico	**UZ**	Uzbekistan
CF	Central African Republic	**JP**	Japan	**NE**	Niger	**VN**	Viet Nam
CG	Congo	**KE**	Kenya	**NL**	Netherlands	**YU**	Yugoslavia
CH	Switzerland	**KG**	Kyrgyzstan	**NO**	Norway	**ZW**	Zimbabwe
CI	Côte d'Ivoire	**KP**	Democratic People's Republic of Korea	**NZ**	New Zealand		
CM	Cameroon			**PL**	Poland		
CN	China	**KR**	Republic of Korea	**PT**	Portugal		
CU	Cuba	**KZ**	Kazakstan	**RO**	Romania		
CZ	Czech Republic	**LC**	Saint Lucia	**RU**	Russian Federation		
DE	Germany	**LI**	Liechtenstein	**SD**	Sudan		
DK	Denmark	**LK**	Sri Lanka	**SE**	Sweden		
EE	Estonia	**LR**	Liberia	**SG**	Singapore		

SIMULATION OF CHEMICAL INTERACTIONS

The present invention relates to a system of elements floating in a liquid, with structural and magnetic characteristics making them bind to each other according to certain rules in response to changes in temperature and use of the system to simulate chemical interactions and catalysis.

Chemical reactions may be viewed as the creation and breaking of bindings between individual elements. Accordingly, catalytic function may by regarded as an element's ability to promote the creation and breaking of bindings between elements.

Biological systems represent complex networks of biochemical elements with interrelated catalytic functions. These elements and their catalytic functions may be directly traced to the DNA molecule and its unique ability to store and replicate molecular information.

DNA is a linear polymer of deoxyribonucleotides. Each deoxyribonucleotide consists of three main groups, 1) a deoxyribose-a pentose sugar, 2) a phosphate group and 3) one of the heterocyclic nitrogenous bases, adenine (A), thymine (T), guanine (G) or cytosine (C)

A double helical DNA molecule consists of two complimentary, antiparallel strands of DNA. The phosphodiester bonds linking the 5' and 3' carbons of the adjacent sugar residues results in directionality of the polynucleotide chain. In the double stranded DNA molecule, the phosphodiester bonds of each polynucleotide chain run in opposite directions (i.e., 5'-3' and 3'-5') and are thus said to be antiparallel. Base pairing between strands is the result of hydrogen bonding between adjacent base pairs. Normally, A residues form 2 hydrogen bonds with T, and G residues form 3 hydrogen bonds with C resulting in complementary base pairing between the DNA strands. Therefore the sequence of bases in one strand determines the sequence of the complementary strand and is the basis of DNA replication. The two strands of DNA coil around a central axis in a right handed manner with the sugar-phosphate backbone on the exterior and the bases on the interior. The aromatic rings of the bases are stacked in the middle, perpendicular to the axis of the DNA double helix. A full rotation in the helical structure comprises ten nucleotides.

The nucleotides in a DNA strand are held together by strong covalent bonds between the phosphate and the sugar residues. The creation and breaking of these bonds requires supply of energy and in present organisms these reactions are catalyzed by energy consuming enzymatic reactions. The bonds between the complementary bases are weak hydrogen bonds and the attractive forces between to single nucleotides are weak. When the nucleotides are organized in DNA strands, large numbers of hydrogen bonds are coordinated, so that the attractive forces between two complementary strands become relatively strong. They are however responsive to heat (below 100°C) and alkali, and are considerably weaker than the covalent bonds composing the individual DNA strands.

All biological systems are based on the ability of the DNA molecule to store and reproduce information. The genetic information is stored in the structure of the DNA molecule as different sequences of nucleotides. Reproducing this information is achieved in that an existing nucleotide chain, via an intricate network of biochemical reactions, catalyzes the creation of a complementary chain.

It is today widely accepted that life on earth evolved from simple molecular structures by means of natural selection. This evolution process, which was first recognized by Charles R. Darwin, explains biological evolution in terms of a simple mechanism directly related to self-replication of biological information.

Human civilization is at present experiencing the early signs of a fast approaching revolution driven by incredible advances in biotechnology. Cloning of mammals is today a reality and genetic manipulation is performed as routine assays in laboratories all over the world. These advances constitute complex challenges to different parts of society, including political as well as private decision making. Consequently, there is a growing need for easily accessible information related to the fundamental aspects of biology. This need can be meet by a system, which in simple manner simulates the fundamental chemical mechanisms underlying all biological systems.

Different systems have been proposed to simulate chemical interactions. In American Scientist, Vol. 47; 261-263, 1959 (H.J. Morowitz) it is suggested a system for simulating replication based on two types of element A and B,

floating in water. A and B can bind to each other, but only if the binding is initiated by an existing complex of A and B. Thus an AB unit can catalyze creation of a new AB unit. Each element carries a battery and an electromagnet. The bindings between A and B elements are, however, not reversible, and the system does not involve the use of natural magnets and ferromagnetism, nor are the inter-elemental bindings controlled or responsive to changes in temperature.

There are a number of known systems for demonstrating molecule structures such as proteins, DNA, or RNA wherein the elements are held together by magnetic forces, glue etc. (DE 23 41 320 A1, SE 15 58 07, US 3,594,924). These systems are, however, all static models, which in no way simulate reversible chemical interactions or catalysis.

In SU 89 66 75 B it is described magnetic elements simulating items «for demonstration in investigating physico-mechanical properties of solids». The magnetic elements are enclosed in an elastic shell and floating in a tank filled with a liquid. The repulsion forces between items can be simulated in addition to elastic properties of solids. This system does not involve reversible chemical interactions simulating catalytic functions, nor the use of temperature as a means for regulating the magnetic forces and the inter-elemental bindings.

Thus there is an object to provide a system for demonstration/simulation of reversible chemical reactions and catalytic function based on temperature dependent ferromagnetic interactions.

These objects are obtained by the present invention characterized by the enclosed claims.

The present invention provides a system of elements floating in a liquid, which can bind together by temperature dependent ferromagnetic binding forces, wherein the elements are physically designed to provide certain characteristics to the inter-elemental bindings, and that the magnetic forces are controlled by temperature. The invention further comprises use of the system to simulate chemical interactions, and catalysis, wherein the bindings are manipulated by varying temperature and turbulence, and by introducing modifying elements, and use of the system as an educational tool, an interactive game, a decoration and a tool for scientific purposes.

In the following the invention will be described in greater detail by referring to the figures, wherein;

Fig. 1 illustrates the architecture of the DNA molecule. Panel 1, describes the four nitrogenous bases, adenine (A), thymine (T), guanine (G) and cytosine (C), and their respective paring A-T and G-C; panel 2, describes a nucleotide comprising a base (a), a phosphate group (c) and a ribose (b); while panel 3 demonstrates how the DNA helix is composed of complementary and antiparallel chains of nucleotides, and also illustrates how the two strands split apart and give rise to two new copies of the double-stranded DNA molecule.

Fig. 2 illustrates schematically how a combination of two inter-elemental bindings (Binding I and II) constitutes the basis of self-replication and an evolutionary process. The two elements A and B bind each other through forces receptive to cyclic temperature changes, so that the binding is created at low and broken at high temperatures (Binding I). The elements connect to form chains when oriented in a favorable geometrical position, by a binding mechanism less influenced by temperature (Binding II). A random chain of elements is created spontaneously (1), at lower temperatures the free floating elements arrange themselves along the existing chain (2), the units are bound together to form a complementary chain and a double chain is created (3), the temperature is increased and the chains depart (4), the temperature drops again and free floating elements arrange themselves along the two chains (5), two double chains are created (6), leading to that the number of chains will increase exponentially (7). New sequences occurs due to miss-incorporations (point-mutation) (7), or as a consequence of rearrangements due to double hybridizing (8) thus resulting in longer chains (9). Chains which in a given environment are more often reproduced will increase in number at the expense of other chains, and thus be selected by means of natural selection (10). This will drive the process towards chains with increasing complexity and better ability to self-replicate.

Fig. 3 illustrates the single element in the system seen from all angels, describes the design of the element.

Fig. 4 illustrates one of the possible bindings, Binding I. This binding is specific for the hydrogen bindings between complementary units (G-C, A-T) representing the respective nucleotides.

Fig. 5 illustrates the second of the possible bindings, Binding II. This binding represents the ribose-phosphate binding in the DNA molecule, which produce the nucleotide chains.

Fig. 6 illustrates that Binding I and II may be connected so that, the magnetic force in Binding I is enhanced for elements already connected by Binding II, causing that chains of the elements have greater attractive forces than free-floating elements. This will discourage mutual blocking between individual complementary elements.

Fig. 7 illustrates the facilitation of the creation of a chain when the temperature in the liquid medium is reduced and a chain is already existing.

Fig. 8 illustrates the creation of a double chained helix, due to the angle 9 (Fig. 1) on the element.

Fig. 9 illustrates separation of the two chains when the temperature of the liquid medium is increased above the T_c for Binding I.

Fig. 10 illustrates the system used to simulate a mutation wherein a different element M is designed, which is able to bind both C and T elements.

Fig. 11 illustrates a total assembly comprising a transparent water tank with a base containing electronically operated thermostats and turbulence generator, connected to a computer for operating and monitoring the temperature and turbulence in the liquid medium.

The most intriguing of all catalytic processes is the self-replicating and adapting process generally recognized as «life». Life on earth has evolved by means of natural selection and it is this fundamental mechanism which underlies the adaptability of biological systems. This adaptability as well as the process of self-replication can be directly traced to the structure and function of the DNA molecule. In present organisms an intricate network of interrelated biochemical reactions orchestrates self-replication of the DNA molecule. In fact one of the most powerful scientific models of biology is to view the complete organism as a vehicle set up by DNA to transfer the

molecular information to the next generation of organisms. It is also widely accepted that life on earth has evolved though an early stage where simple molecular structures, probably related to the RNA molecule, replicated without the complex biochemistry of present organisms. This hypothesis is based on the fact that the RNA molecule combines the ability of replication with powerful catalytic functions. However, although the principle of self-replication and adaptability may be deduced from the structure of the DNA molecule, it has proven extremely difficult to construct artificial molecular systems which combines these two hallmarks of life, thus facilitating evolution by means of natural selection. It was thus a great surprise to the inventor when he after considerable trial and error, realized that such a system could be constructed, not from chemistry, but from carefully designed solid-phase elements, floating freely in a liquid.

The following criteria must be met for a system to simulate an evolutionary process.

1. Reproduction: The element carrying the information must increase the probability for its own reproduction in its own environment.

2. Mutagenesis: The reproduction process must include a certain error tendency to create a repertoire of variants, which can be selected by the environment, a process referred to as natural selection.

3. Death: The system must involve recycling of the information carrying elements, such that the process is open-ended.

In order to provide such characteristics to a system based on free-floating physical elements, each element must comprise the ability to reversibly bind to each other, according to a set of roles, and in response to specific changes in the environment.

The inventor tried different alternatives for constructing such binding mechanisms, and came up with a number of possible solutions, including a combination of different systems comprising mechanical locking and mucous glues with temperature dependent adherence. Solutions comprising magnetic bindings provided however a unique way of binding since magnetic forces work across distances and involve specificity related to the positive and negative poles. In fact the previously described system by Morowitz describes how a system of elements with an intrinsic power supply and

electromagnetic switches can simulate self-replication. However, this solution related to power-supplies and electromagnetism comprises costly arrangements in a system intended to involve several thousand elements. The inventor therefore continued to search for a less costly solution to the problem and contemplated the use of hard (permanent) magnetic materials. There is no obvious way by which binding between such materials are reversible, besides the fact that hard magnets become permanently inactivated when heated to extreme temperatures. The inventor found, however, that a combination of a hard and a soft (temporary) magnets constitutes a persisting reversible magnetic binding receptive to temperature changes in a range comprising the Curie point (T_c) of the soft magnet. This construction offers a surprisingly simple solution to the above-described problems involving materials that are commercially available and inexpensive. Furthermore, in contrast to the system by Morowitz, the bindings in the present invention are responding to changes in the environmental temperature, which in a unique manner simulates the breaking of chemical bindings in response to heat or other sources of energy. There are several soft magnets with T_c ranging from 10°C to 40°C, such as Fe-Ni alloys, amorphous alloys and soft ferrites, making it possible to select materials for breaking and reestablishing magnetic bindings by temperature fluctuations around room temperature.

Inexpensive, elements that demonstrate chemical interactions and catalytic functions constitutes a new and surprising invention, which can be designed to address a number of different questions related chemistry and the behavior of complex systems. However, based on the forthcoming biological revolution it seems rational to design a model of elements behaving as «ideal nucleotides», i.e. elements which interacts according to the roles of nucleotides, but without the need for a complex biochemical machinery to catalyze these interactions.

To simulate the characteristics of nucleotides and DNA/RNA molecules, a simulation of the chemical interactions between these molecules must be included. Simulation of such chemical interactions should; 1) be reversible; 2) be specific; 3) also allow some degree of unspecific binding, and; 4) the bindings must be receptive to controllable changes in the environment of the element.

According to the present invention this can be accomplished by the use of magnetic materials with different T_c, combined such that it is possible to create a system wherein specific bindings are broken at specific temperatures. By regulating the temperature it is possible to control the forces acting between the elements in the system. Thus this system is analogous to a chemical system wherein the weak hydrogen bindings are broken at low temperatures, while to break the covalent bindings increased energy supply is necessary.

The present invention thus relates to a system of elements floating in a liquid designed to interact due to their magnetic and mechanical characteristics to simulate reversible chemical interactions, which can be designed in a wide range of shapes and sizes.

The following example relates to an application of the invention that simulates the structure, function, and molecular evolution of nucleic acids. The elements of the system are shown in Fig. 3. In one embodiment they are approximately 10 mm x 10 mm x 3 mm, made of suitable materials, such as for example plastic and with a density similar to the density of water in the temperature range from 10°C to 40°C. Each element comprises imbedded hard magnets and soft magnets in a pattern making possible bindings between only specific elements of choice.

The edge 1 of the element provides the contact surface between two elements bound by Binding I, due to imbedded magnets below the surface. The semisylindrical surface of the edge 1 makes possible hinge like movement of the two elements, relative to each other. In one end of the edge 1 there is a cut-out 3, in the other end a tip 2 which fits into the cut-out 3 on the complementary element, causing Binding I to be directional, i.e. the elements bound points in opposite directions (Fig. 4). In one lateral edge, oriented in relation to the edge 1, there is a recess 5 with a peg 4 housing a soft magnet with T_c higher (for example 30°C) than the T_c of the soft magnets in the edge 1. The magnet imbedded in the peg 4 is protected by the recess 5 to assure that Binding II never/seldom shall occur spontaneously and to prevent that a binding shall result between the magnet in the peg 4 and the magnets imbedded in the edge 1. Contralaterally to the recess 5 is a projection 6 with a spherical head 7 containing a hard magnet to attract the magnet imbedded in the peg 4. The head 7 has a slit 8 in the extension of the projection 6 to shield the magnet to prevent Binding II occurring

spontaneously and prevent binding between the magnet in the head 7 and the magnets in edge 1. The projection 6 fits into the recess 5 and when Binding II is activated the elements may rotate about an axis through projection 6. Binding II has to a certain degree a hinge function since the projection 6 may slightly top over in the recess without breaking the binding. Diagonally from the tip 2 to the projection 6 runs an axis 9 around which the element is angled. The two parts of the element thus describe the legs of an angle of 36°. The recess 5 and the projection 6 are thus oriented in different planes and a double chain of elements will create a helix comprising 2 x 10 units in each rotation. This angled surface of the element facilitates further that the extension of a chain preferably occurs in the end of the chain carrying a recess 5, which simulates that the DNA synthesis occurs from the 3' end.

Fig. 4 illustrates Binding I and the pattern of hard and soft magnets to make possible that only element G links to element C and element A to T. This binding simulates H-bonds in the DNA molecules, and the G-C binding comprises 3 sets of magnets while the A-T binding comprises 2 sets of magnets, corresponding to 3 H-bonds and 2 H-bonds respectively between the bases. Accordingly the G-C binding is stronger than the A-T binding which promote the different characteristics of the different sequences of elements.

The imbedded magnets (10, 11, 12) have the following characteristics:

The magnet 10 is a permanent hard magnet, made of for example neodymium, oriented with the positive pole towards the contact surface. Since all hard magnets are such oriented they are not attracted to each other and Binding I is specific for G-C and A-T elements respectively. Covering the positive pole of the magnet 10 is a hood 11 enveloping the outer end of the magnet and consisting of a soft magnetic material, made of for example a amorphous alloy, with T_c in the temperature range, for example approximately 25°C, in which Binding I is broken. This hood 11 mediates the magnetic forces from the hard magnet 10 to the contact surface 1 of the element (Fig. 3) only when the temperature is below T_c. When the temperature is above T_c the contact surface 1 is demagnetized. The soft magnet 12 is made of the same material as the hood 11 and has a $T_c = 25°C$. The localization is designed to interact with the magnetic forces of the hard magnet located in the opposite position in the complementary element. The

demagnetization of the soft magnet 12 at temperatures above approximately 25°C promotes breaking of Binding I.

Fig. 5 illustrates Binding II, which simulates the ribose-phosphate binding in the DNA molecule producing the nucleotide chains. Binding II is maintained by the hard magnet 13, e.g. made of the same material as magnet 10, oriented with the positive pole towards the slit 8. This magnet is covered with the hood 14, made of a soft magnetic material with a T_c higher than for the soft magnets in Binding I, say 30°C, (Fig. 3). Magnet 13 is magnetizing the soft magnet 15 located in the peg 4 in the complementary element. The soft magnet 15 is made of similar material as the hood 14, with $T_c = 30°C$. Thus Binding II is maintained at temperatures below 30°C. The different demagnetizing temperatures for Binding I and II makes the last more resistant to higher temperatures. When the ambient temperature cycle around 25°C only Binding I will be affected. Binding II breaks only when the ambient temperature is increased above 30°C.

Binding II allows the elements to rotate around the projection 6 (Fig. 3). Furthermore the direction of the slit 8 makes possible movement of the bound elements in a plane through the projection 6 (Fig. 1), vertically on the figure plane (Fig. 3). The described mobility of Binding II may lead to several secondary structures which will produce different characteristics, since structure and function are interrelated.

Since Binding II is made by magnets protected by the slit 8 and the recess 5, this binding will never/seldom come into being spontaneously between free-floating elements.

Fig. 6 describes an embodiment of the invention wherein the elements are modified such that the magnetic forces in Binding I are enhanced when Binding II is activated.

The elements of this embodiment comprise the magnets 10, 11, 12, 13 and 14 described above. In addition each element contains a bridge comprising a soft magnet 16, with $T_c = 30°C$, located inside the peg 4 and in contact with another soft magnet 17, with $T_c = 25°C$, which ends at the contact surface 1 for Binding I between the magnets 10 and 12, opposite to an additional soft magnet 18 in the complementary element.

This arrangement will make Binding I stronger when the temperature is below 25°C which is the temperature at which Binding I is broken. In this embodiment the elements already united in chains will exercise greater attractive forces than free-floating elements, and will thus reduce the trend that free-floating elements are blocking each other.

Figure 7 illustrates that an existing chain will spontaneously facilitate the creation of complementary chains when the ambient temperature cycles above and below the T_c for Binding I. Thus when the temperature is lowered the elements already chained together will attract free floating complementary elements and bind them via Binding I. This binding will then function as a hinge in that the newly bound elements will move back and forth around an axis through the contact surfaces 1, and cause that elements in juxtaposition will be geometrically in good position for spontaneously creation of Binding II, thus producing a new chain.

Figure 8 illustrates the creation of the helix structure of the double chain, due to the angle 9 of the surface of the element, thus simulating the DNA helix structure.

Figure 9 illustrates use of the system according to the invention to simulate denaturation of the DNA molecule by increasing the temperature. In the system according to the invention increasing the ambient temperature above the T_c for Binding I will break the binding, and the two chains will separate.

Figure 10 illustrates how the invention can simulate creation of a mutation. Mutagenes are agents inducing exchange of bases in the DNA molecule and can be for example chemicals changing the characteristics of the bases abolishing their ability to code specifically. In the system of the present invention an element M is constructed, which due to the pattern of magnets can bind (Binding I) to both the C element and T element.

Furthermore it is possible to construct mutagenic elements with a defect in the ability to create Binding II. This will result in shorter chains.

The system according to the invention can also be designed to simulate a primitive translation process wherein the genetic information in the DNA molecule is translated to chains of amino acids. In present organisms this process is performed by complex biochemical mechanisms involving cellular organelles called ribozomes. Resent findings suggest however that the

evolutionary basis of this process be related to direct affinity between different amino acids and specific triplets or codons of nucleotides. The combination G-C-A in a chain of nucleic acids may e.g. attract the amino acid alanine. An exciting nucleotide chain may thus promot chains of amino acids in a similar manner as complementary strands are created.

In the present system an element Aa simulating an amino acid is designed to bind to the contact surface 1 of three specific elements of the simulated DNA chain, with which the following creating of a binding (corresponding to Binding II) for creating a chain of amino acids to simulate a peptide or protein. By varying the pattern of magnets imbedded in the contact surface 1 of the Aa elements, different amino acids, binding to different codons of elements are designed.

Still further embodiments of the invention may comprise elements simulating biological co-factors with the ability to interfere with or facilitate binding of specific elements.

In a further embodiment the magnetic forces in the elements can be produced by electromagnets powered by small photovoltaic units on each element. In this case the evolutionary process is powered by changes in the electromagnetic radiation instead of water temperature. These two mechanisms may also be combined.

Figure 11 illustrates a container for liquid, such as water, with transparent wall for example 150 cm tall and 65 cm in diameter, containing 500 l of liquid. The container has a base with an electronically operated thermostat and turbulence generator, connected to a programmable unit for regulation of liquid temperature and turbulence, for example a computer.

Simulation of self-replication and mutation

1. As a start situation a large number of different elements, such as 2500 of each of the four types, are floating freely in the liquid such as water of the container (Fig. 11), and the temperature of the liquid is between T_c for Binding I and II, such as 28°C.

2. The first chain can be created
   a) spontaneously via Binding II, which has been designed to be a slow process due to the location of the magnets 13, 14 and 15,

or

b) by constructing a chain of elements and add this chain to the container.

3. A new chain is then created by lowering the water temperature below the T_c for Binding I, such as for example 20°C. Free elements will bind to complementary elements (G-C, A-T) in the template chain, and neighboring elements will be connected by Binding II as described above, simulating elongation of the chain. When the chain is elongated the total binding becomes stronger since an increasing member of magnetic bindings are holding the chains together.

The result is creation of a simulated DNA helix.

Chain reaction: To facilitate a chain reaction it will be necessary to let the water temperature cycle between for example 20°C and 28°C, i.e. below and above the T_c for Binding I. New chains will then be created as described above and when Binding I is broken by increasing the temperature the number of template chains are doubled. This results in an exponential increase of the number of chains in the container.

Recirculation or death: A chain will dissolve if the water temperature is increased above the T_c for Binding II. Balanced or specific death of certain chains can be obtained by regulating temperature and turbulence in such a way that short pulses of water with a specific temperature hit a group of chains.

Mutations: Point mutations will appear spontaneously by incorporation of different mutagenic elements in the chains. These mutagenes can be of the type suggested in Fig. 10, wherein Binding I is affected or a type wherein Binding II is affected (not shown).

Mechanical stress, deficient Binding II or high temperature will produce shorter chains, while longer chains can be produces when one chain binds two other chains (double hybridization) (Fig. 2) or because Binding II occurs spontaneously. A chain of 10 elements can be varied $4^{10} = 10^6$ different ways while a length of 20 elements gives 10^{12} possible combinations. If one new chain of 20 elements is produced every minute, testing of all combination will require 2×10^6 years.

Natural selection

Mutants, which for any reason are more reproducible, will increase in number at the expense of others. Such advantageous characteristics can be;

- Secondary structures stabilizing the chain such that it is resistant to breaking when the temperature is increased,
- secondary structures inhibiting the replication of other chains (simulating natural ribozymes),
- secondary structures «taking advantage» of other elements in the solution,
- sequences adapted to the distribution of elements, and
- chains cooperating with other chains.

The direction of the evolutionary process will be modified by the environment in the container (temperature and turbulence profile, concentration of elements, presence of other chains and elements). The selection process will drive the system towards better replication rates and increasing complexity.

Applications

The system according to the present invention involves a general tool for demonstrating/simulating chemical interactions, catalytic functions and the behavior of complex systems. It can be particularly designed to demonstrate self-replication and evolution by means of natural selection and offers as such several areas of application.

Education: The system is, as demonstrated above, able to simulate the fundamental characteristics of life in a manner that is easily understandable by children and adults. The system mediates biologically and evolutionary knowledge and can be used as educational tools for general and molecular biology. It can furthermore be combined with a computer based multimedia educational system, suitable for different age groups and competence levels. The programmable unit according to the invention (Fig. 11) can be used with suitable software and hardware to develop programmable temperature and

turbulence profiles favoring different type of chains and thereby guide the evolutionary process in different directions, protocol the development of old and new chains and map the characteristics of different chains, for example possible secondary structures.

Games: An evolutionary system comprise a form of «life» and the challenge will be to «breed» new and steadily more robust and complex «species» of this form of life, by playing with the environment (temperature, turbulence, additional elements) to increase the probability for the creation and well being of certain chains. The challenge is then stepped up to a higher level by placing the above-created chain in a container with another sequence. The two sequences are then parts of each others environment, which may lead the evolutionary process in new directions. Some sequences may be destroyed in the competition while other may cooperate on the replication process.

By using electronic communication applications, e.g. the Internet, various sequences and their characteristics may be exchanged and the evolutionary process has expanded beyond its own container.

The challenge of this game will be to produce sequences, which compete with other under varying conditions. The sequences may be named and made known via Internet.

Scientific tool: This invention represents an artificial replication system comprising the ability to evolution by means of natural selection, and will as such represent an independent scientific achievement. Furthermore, the invention constitute a new and unique tool for simulating and investigating the behavior of complex systems, particularly related to the characteristics of self-replication and natural selection. Additionally, the specific hybridization between polymers may be applied as means for calculation, an application that has been extensively demonstrated for nucleic acids (DNA computing).

Sculpture, decoration and exhibitions: The system according to the present inventions has dynamic characteristics, which may be visually appealing. Thus it is possible to use the system to create new and visually appealing physical structures, not only in the form of helical structures resembling the DNA molecule. Furthermore a reproducible system for swimming pools, can be designed for decoration purposes and/or as toys.

CLAIMS

1. System of elements floating in a liquid which can reversibly connect to each other by magnetic forces,
c h a r a c t e r i z e d i n that the inter-elemental bindings involve magnetic materials with Curie point within a temperature range corresponding to temperature changes in the environment of the elements.

2. System according to claim 1,
c h a r a c t e r i z e d i n that the elements are physically designed to provide certain characteristics to the inter-elemental bindings.

3. System according to claim 1 - 2,
c h a r a c t e r i z e d i n that specific inter-elemental bindings involve magnetic materials with different Curie points such that specific bindings are receptive to specific changes in temperature.

4. System according to claim 1 - 3,
c h a r a c t e r i z e d i n that single elements or complexes of elements bind to other elements in a manner which promotes or catalyzes new bindings which never or rarely occurs spontaneously.

5. System according to claim 1 - 3,
c h a r a c t e r i z e d i n that single elements or complexes of elements bind to other elements in a manner which promotes or catalyzes breaking of bindings which never or rarely breaks spontaneously.

6. System according to claim 1 - 5,
c h a r a c t e r i z e d i n that the elements are floating in a liquid with a density close to the density of the elements.

7. System according to claim 1 - 7,
c h a r a c t e r i z e d i n that the system include devices for controlling the temperature and the turbulence surrounding the elements.

8. System according to claim 1 - 8
c h a r a c t e r i z e d i n that the elements are floating in a transparent container.

9. System according to claim 8 - 9,
characterized in that the controlling device involves a programmable unit, e.g. a computer, which may be connected to an electronic communication network, e.g. the Internet.

10. Use of the system according to claims 1 - 9 as a device for demonstrating/simulating chemical interactions, catalytic functions, molecular evolution, and the behavior of complex systems, for education, entertainment, decoration, computational, and scientific purposes.

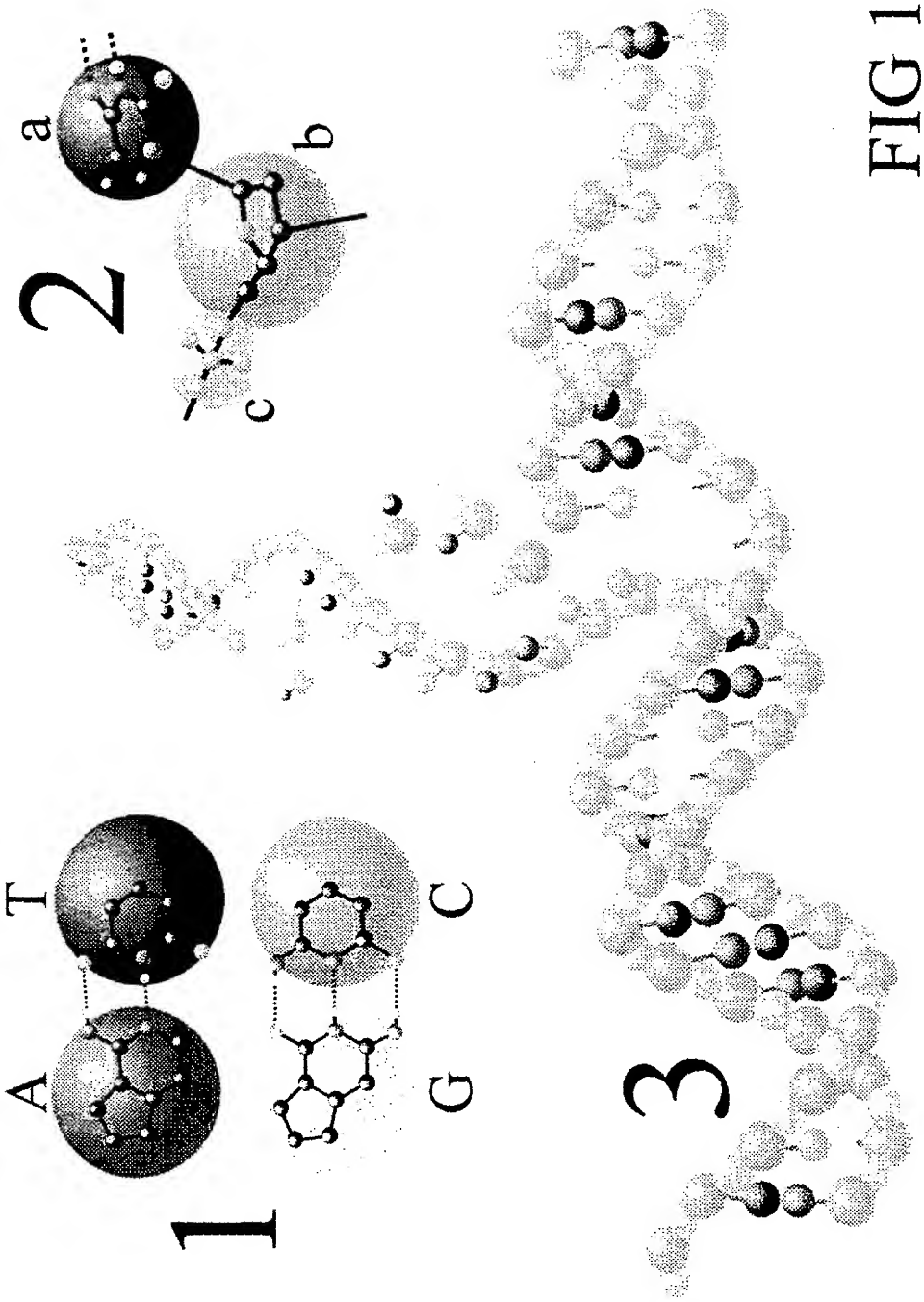


FIG 1

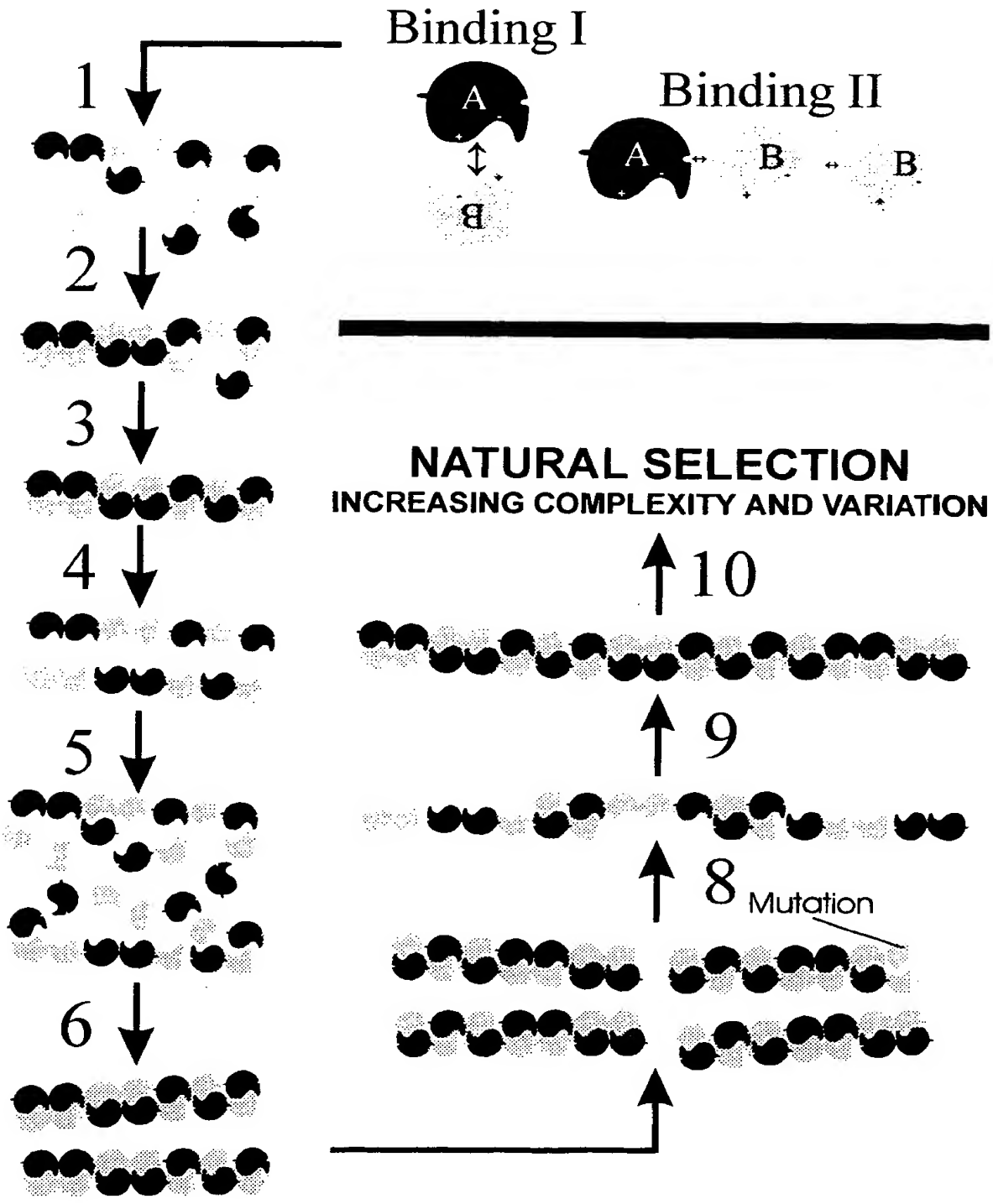

Binding I
Binding II
A
A
B
B
1
2
3
4
5
6
NATURAL SELECTION
INCREASING COMPLEXITY AND VARIATION
10
9
8
Mutation

FIG 2

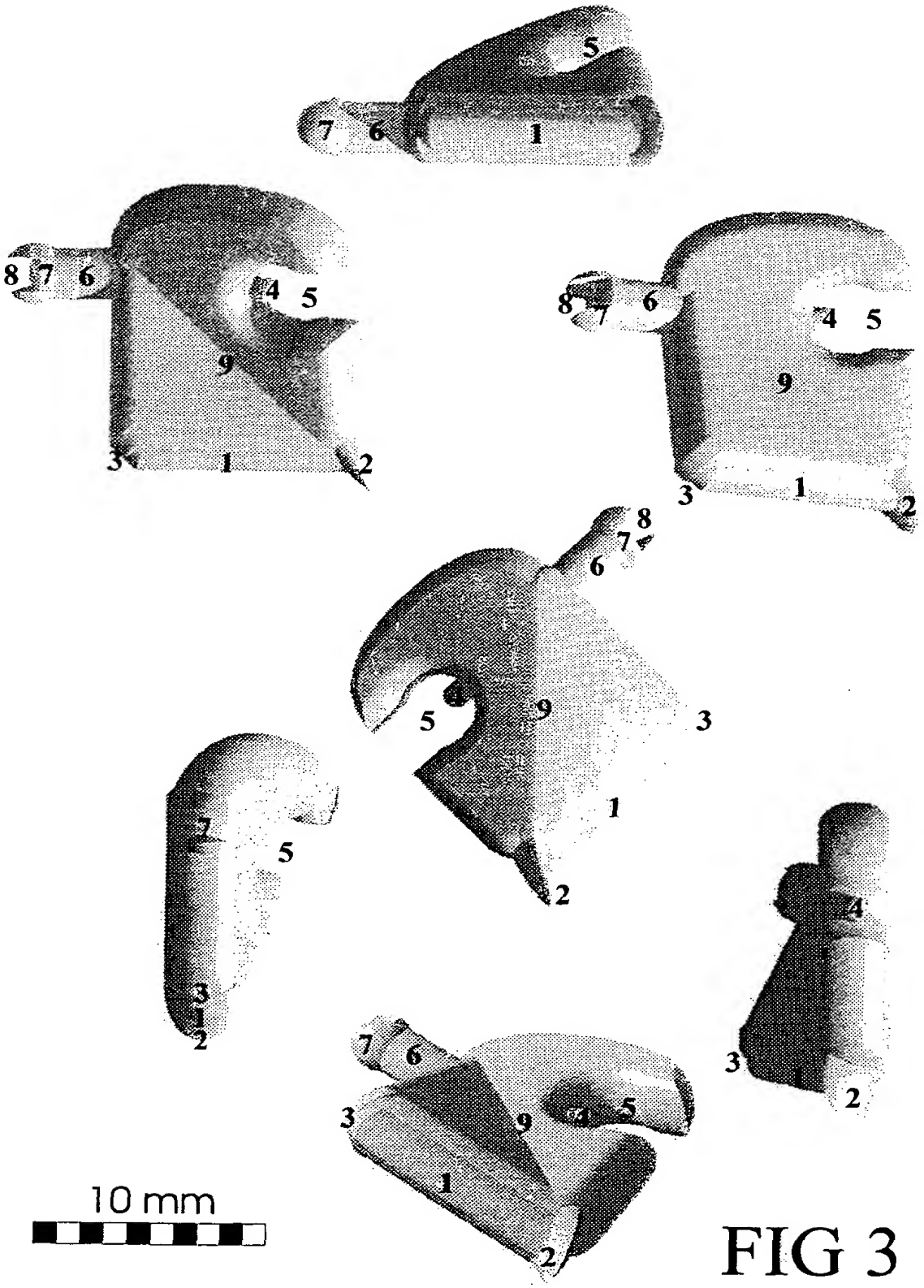


FIG 3

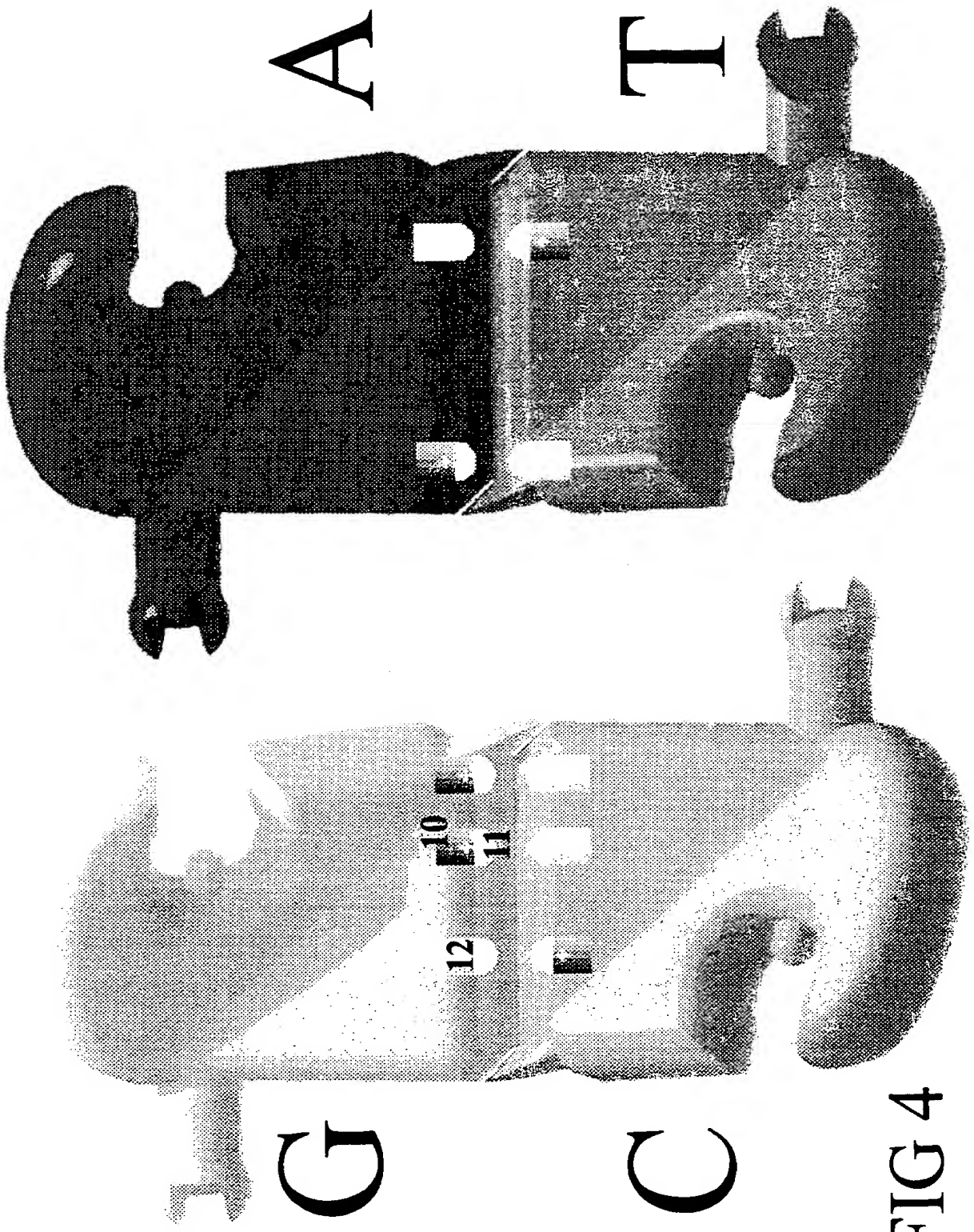


FIG 4

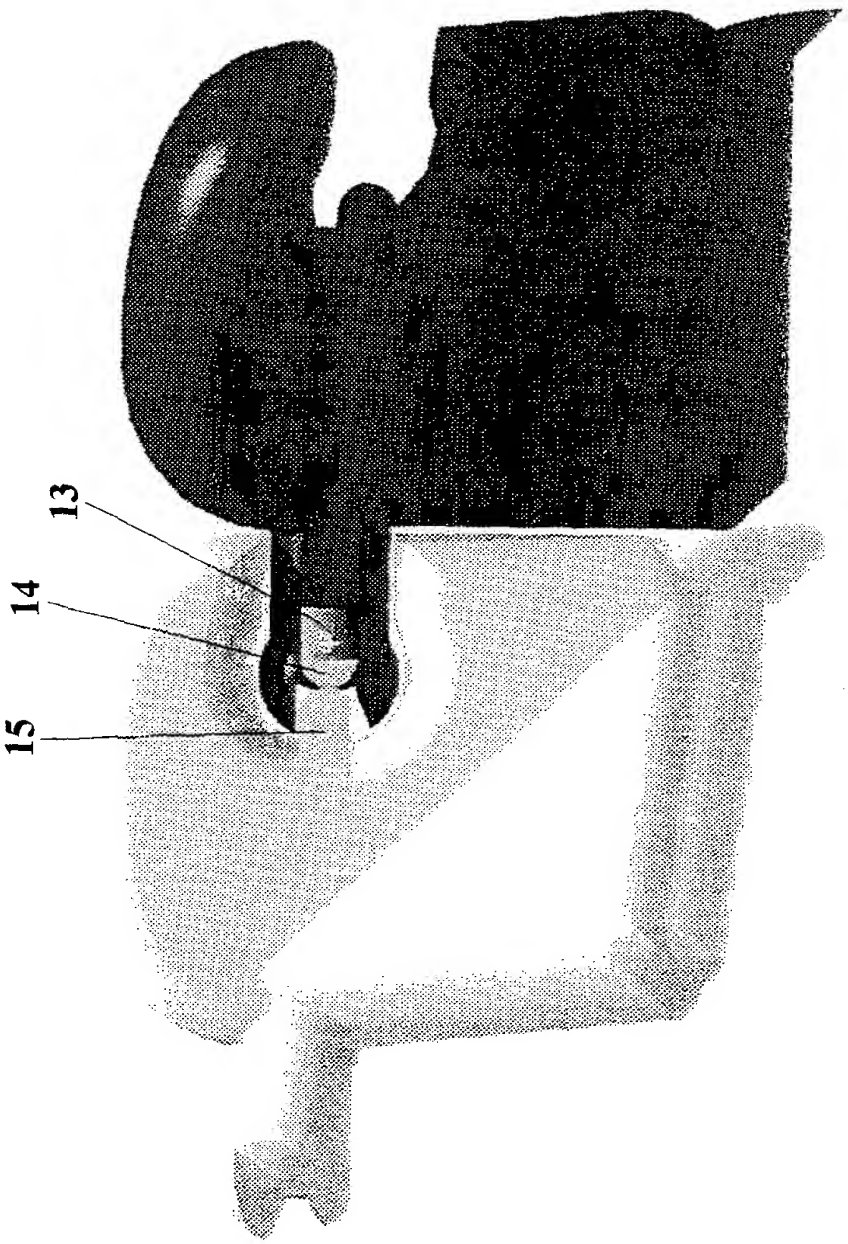


FIG 5

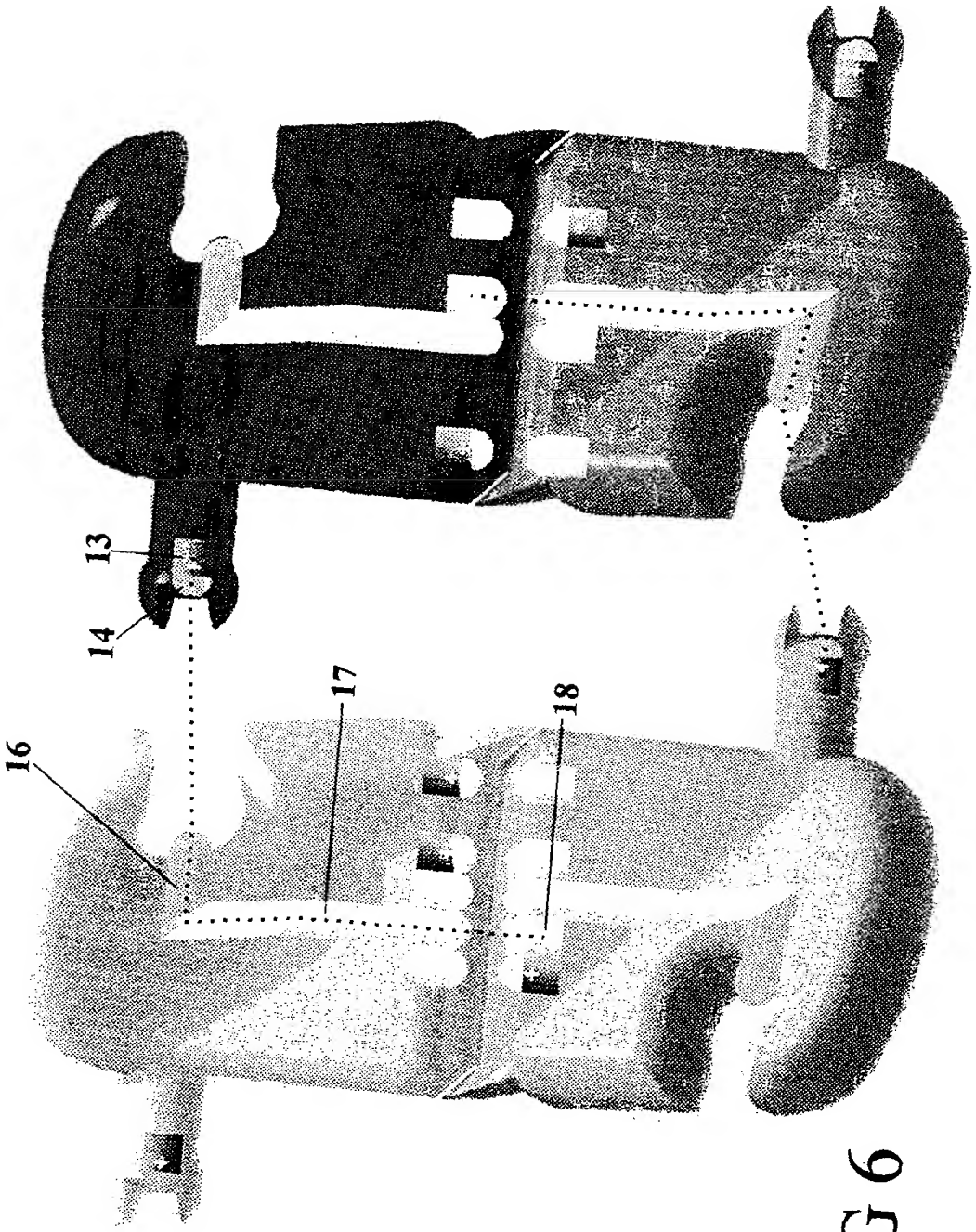


FIG 6

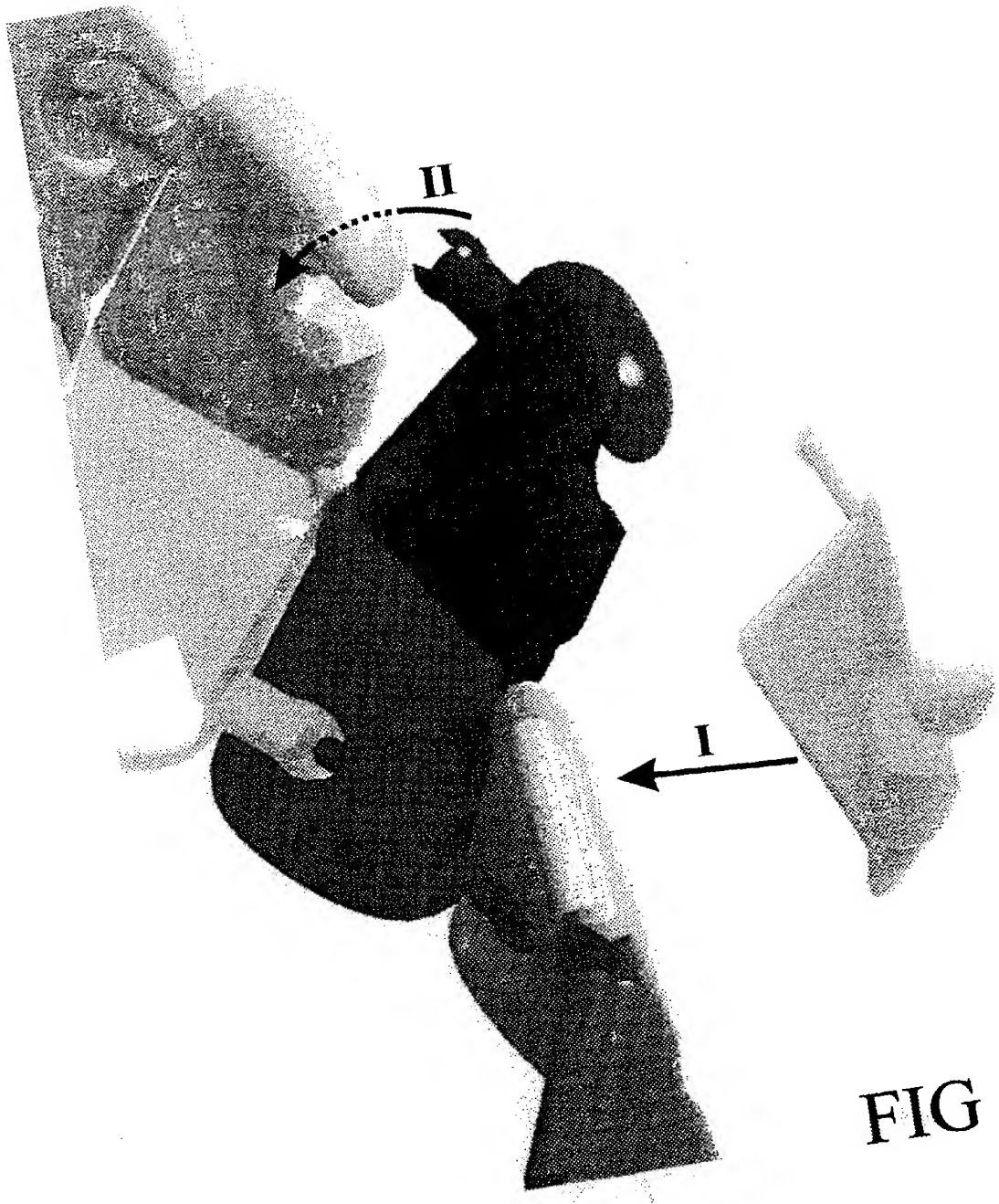


FIG 7

FIG 8

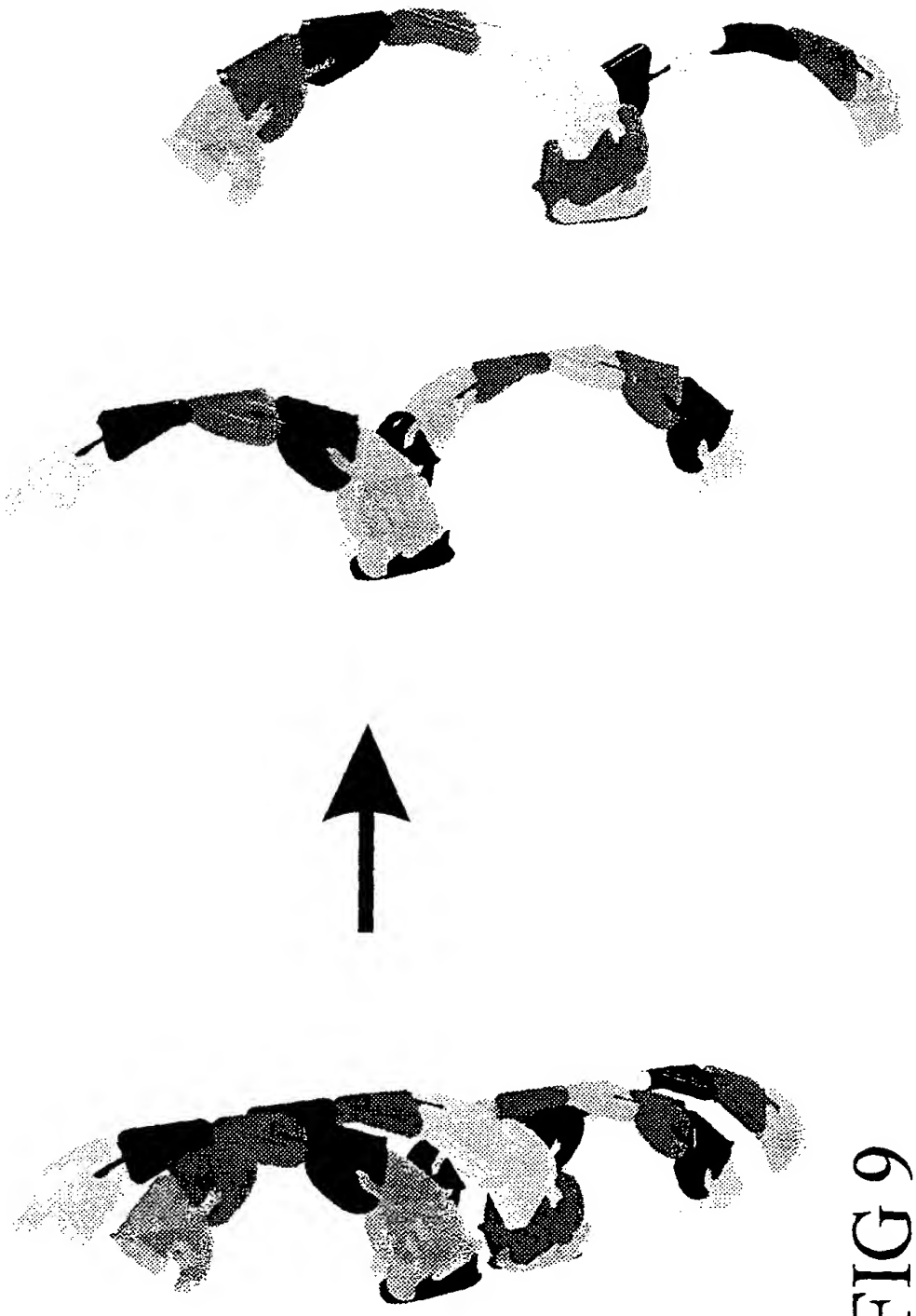


FIG 9

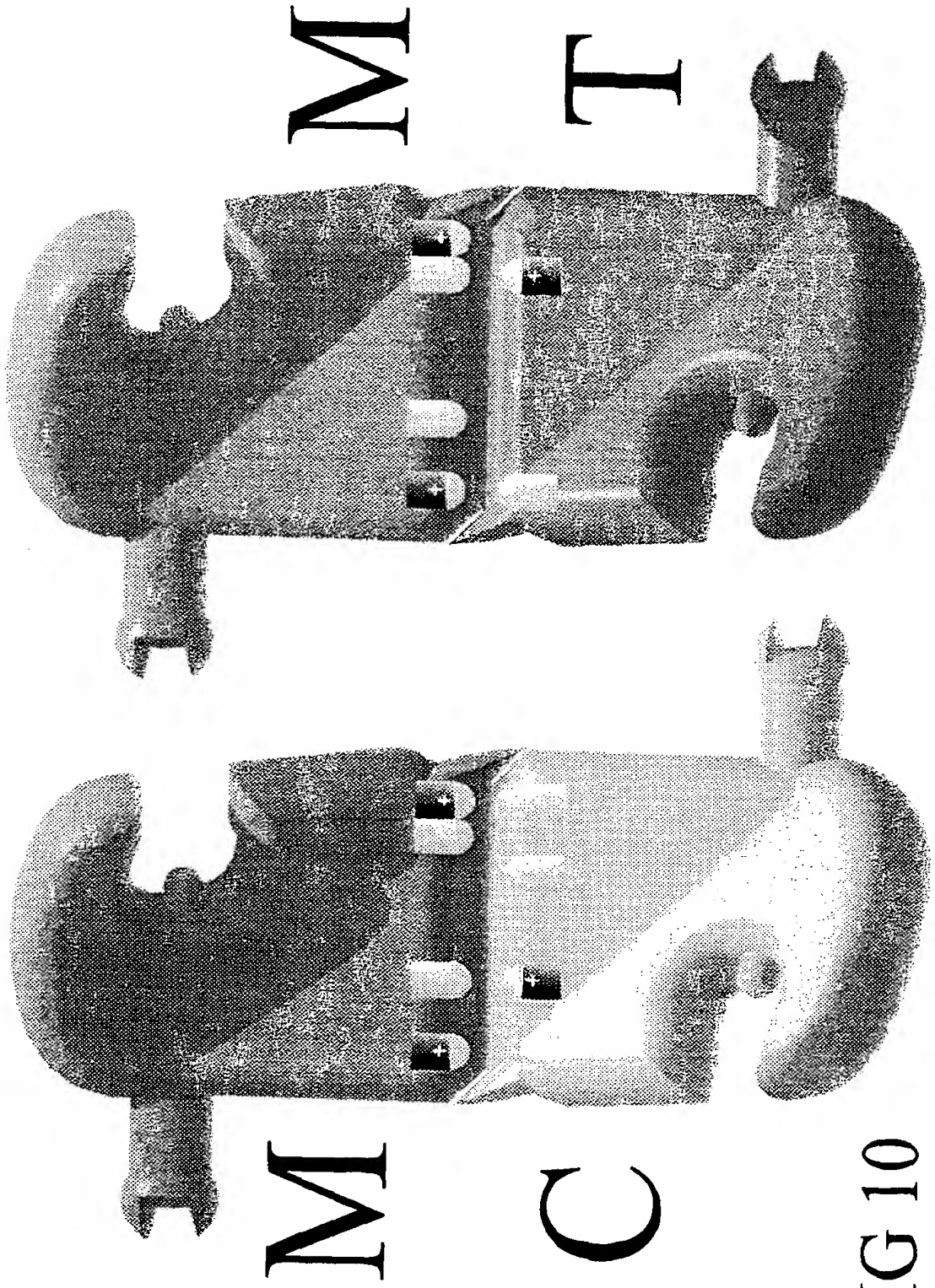


FIG 10

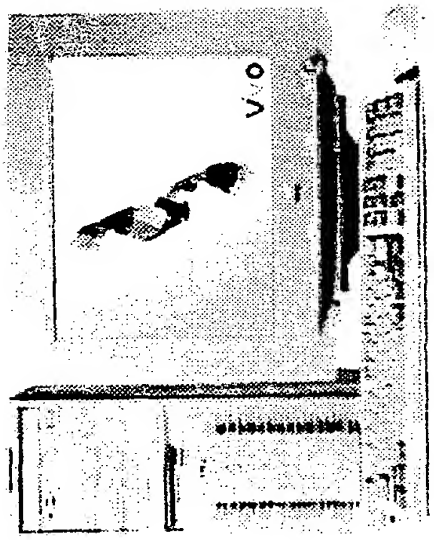
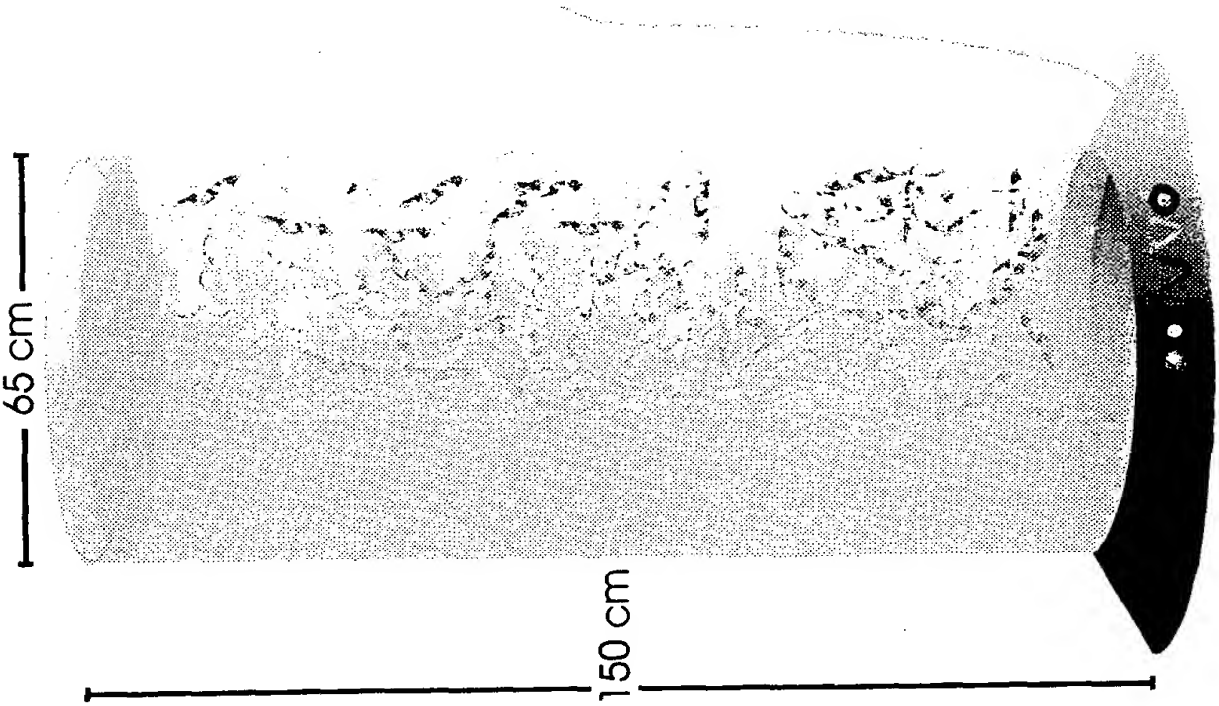


FIG 11



INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00335

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G09B 23/00 // G09B 23/26, G09B 23/24
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DE 3502968 A1 (KARFUNKEL, H.), 31 July 1986 (31.07.86), the whole document ---	1-10
A	Derwent's abstract, No P8316 E/45, week 8245, ABSTRACT OF SU, 896675 (AS UKR PHYS MECH IN), 7 January 1982 (07.01.82), the whole document ---	1-10
A	US 4846988 A (A.T. SKJELTORP), 11 July 1989 (11.07.89), the whole document ---	1-10

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 March 2000	04.04.00

Name and mailing address of the International Searching Authority
European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk
Tel(+31-70)340-2040, Tx 31 651 epo nl,
Fax(+31-70)340-3016

Authorized officer
Johan Löfstedt / MR
Telephone No.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00335

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	American Scientist, Volume 47, 1959, HAROLD J. MOROWITZ, "A model of reproduction" page 261 - page 263 -- --------	1-10

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/NO 99/00335

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3502968 A1	31/07/86	NONE	
US 4846988 A	11/07/89	AT 28766 T	15/08/87
		EP 0163684 A,B	11/12/85
		JP 61500567 T	27/03/86
		NO 834118 A	13/05/85
		WO 8502286 A	23/05/85

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 06 July 2000 (06.07.00)	
International application No. PCT/NO99/00335	**Applicant's or agent's file reference** PAT2
International filing date (day/month/year) 05 November 1999 (05.11.99)	**Priority date** (day/month/year) 11 November 1998 (11.11.98)
Applicant BREIVIK, Jarle	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

08 June 2000 (08.06.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Manu Berrod
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

copending application 09/831,537

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : G09B 23/26 // 23/00 — A1

(11) International Publication Number: **WO 00/28507**

(43) International Publication Date: 18 May 2000 (18.05.00)

(21) International Application Number: PCT/NO99/00334

(22) International Filing Date: 5 November 1999 (05.11.99)

(30) Priority Data:
19985263 11 November 1998 (11.11.98) NO

(71)(72) Applicant and Inventor: BREIVIK, Jarle [NO/NO]; Åsensvingen 5C, N–0488 Oslo (NO).

(74) Agent: ONSAGERS AS; P.O. Box 265 Sentrum, N–0103 Oslo (NO).

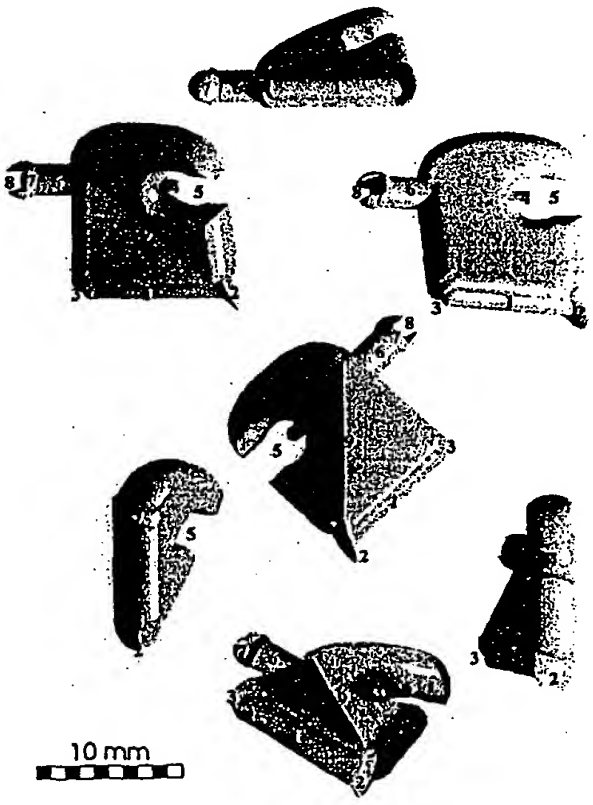
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CR, CU, CZ, DE, DK, DM, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: SYSTEM WHICH CAN REVERSIBLY REPRODUCE ITSELF

(57) Abstract

It is described a system of independently moving elements with characteristics making them bind reversibly to each other according to certain rules such that they form self–replicating and mutating polymers subject to the general principles of natural selection, and use of the system to simulate the origin of life, for entertainment, decoration, scientific and educational purposes.



System which can reversibly reproduce itself

The present invention relates to a system of independently moving elements with characteristics which make them bind reversibly to each other according to certain rules such that they form self-replicating and mutating polymers subject to the general principles of natural selection, and use of the system to simulate the origin of life and molecular evolution.

Self-replication and adaptability are the hallmarks of what is recognize as living systems, and in all biological systems both these properties are directly related to the structure and function of nucleic acids,,i.e. DNA and RNA.

DNA is a linear polymer of deoxyribonucleotides. Each deoxyribonucleotide consists of three main groups, 1) a deoxyribose-a pentose sugar, 2) a phosphate group and 3) one of the heterocyclic nitrogenous bases, adenine (A), thymine (T), guanine (G) or cytosine (C)

A double helical DNA molecule consists of two complimentary, antiparallel strands of DNA. The phosphodiester bonds linking the 5' and 3' carbons of the adjacent sugar residues results in directionality of the polynucleotide chain. In the double stranded DNA molecule, the phosphodiester bonds of each polynucleotide chain run in opposite directions (i.e., 5'-3' and 3'-5') and are thus said to be antiparallel. Base pairing between strands is the result of hydrogen bonding between adjacent base pairs. Normally, A residues form 2 hydrogen bonds with T, and G residues form 3 hydrogen bonds with C resulting in complementary base pairing between the DNA strands. Therefore the sequence of bases in one strand determines the sequence of the complementary strand and is the basis of DNA replication. The two strands of DNA coil around a central axis in a right handed manner with the sugar-phosphate backbone on the exterior and the bases on the interior. The aromatic rings of the bases are stacked in the middle, perpendicular to the axis of the DNA double helix. A full rotation in the helical structure comprises ten nucleotides.

The nucleotides in a DNA strand are held together by strong covalent bonds between the phosphate and the sugar residues. The creation and breaking of these bonds requires supply of energy and in present organisms these reactions are catalyzed by energy consuming enzymatic reactions. The bonds between the complementary bases are weak hydrogen bonds and the

attractive forces between two single nucleotides are weak. When the nucleotides are organized in DNA strands, large numbers of hydrogen bonds are coordinated, so that the attractive forces between two complementary strands become relatively strong. They are however responsive to heat (below 100°C) and alkali, and are considerably weaker than the covalent bonds composing in the individual DNA strands.

All biological systems are based on the ability of the DNA molecule to store and reproduce information. The genetic information is stored in the structure of the DNA molecule as different sequences of nucleotides. Reproducing this information is achieved in that an existing nucleotide chain, via an intricate network of biochemical reactions, catalyzes the creation of a complementary chain.

It is today widely accepted that life on earth evolved from simple molecular structures by means of natural selection. This evolution process, which was first recognized by Charles R. Darwin, explains biological evolution in terms of a simple mechanism directly related to self-replication of biological information.

Human civilization is at present experiencing the early signs of a fast approaching revolution driven by incredible advances in biotechnology. Cloning of mammals is today a reality and genetic manipulation is performed as routine assays in laboratories all over the world. These advances constitute complex challenges to different parts of society, including political as well as private decision making. Consequently, there is a growing need for easily accessible information related to the fundamental aspects of biology. This need can be meet by a system, which in a simple manner simulates the biochemical and evolutionary mechanisms underlying the phenomenon commonly recognized as life.

Different systems have been proposed to simulate self-replication. In American Scientist, Vol. 47; 261-263, 1959 (H.J. Morowitz) it is suggested a system for simulating replication based on two types of element A and B, floating in water. A and B can bind to each other, but only if the binding is initiated by an existing complex of A and B. Thus an AB unit can catalyze creation of a new AB unit. Each element carries a battery and an electromagnet, but are also suggested to be powered by «solar batteries». The

described elements can, however, only combine to form AB units, and the system cannot proceed further to form more complex structures like polymers. Consequently this system can neither generate mutations, nor simulate evolution by means of natural selection. Furthermore, the binding between A and B elements is not reversible so there is no possibility of re-circulation (death) of the elements such that the process is open-ended. This system does not involve the use of natural magnets and ferromagnetism, nor is it any obvious manner by which such material could be used.

There are a number of known systems for demonstrating molecule structures such as proteins, DNA, or RNA wherein the elements are held together by magnetic forces, glue etc. (DE 23 41 320 A1, SE 15 58 07, US 3,594,924). These systems are, however, all static models, which in no way simulate reversible chemical interactions, self-replication or evolutionary processes.

In SU 89 66 75 B it is described magnetic elements simulating items for demonstration of physico-mechanical properties of solids. The magnet elements are enclosed in an elastic shell and floating in a tank filled with a liquid. The repulsion forces between items can now be simulated in addition to elastic properties of solids. This system does not simulate self-replication or evolutionary processes, nor is it suggested to do so.

Thus there is an object to provide a system for demonstration/simulation of open-ended self-replication of polymers and the principle of evolution by means of natural selection.

These objects are obtained by the present invention characterized by the enclosed claims.

The present invention provides a system of independently moving elements with characteristics which make them bind to each other according to certain rules such that they form self-replicating and mutating polymers subject to the general principles of natural selection, and use of the system to simulate the origin of life and molecular evolution. The invention further comprises use of the system to simulate self-replication and natural selection of nucleic acids, wherein the evolution process is promoted and manipulated by controllable changes in the environment of the elements, e.g. temperature, light and turbulence, and by introducing modifying elements, and use of the

system as an educational tool, an interactive game, a decoration and a tool for scientific purposes and computational purposes.

In the following the invention will be described in greater detail by referring to the figures, wherein;

Fig. 1 illustrates the architecture of the DNA molecule. Panel 1, describes the four nitrogenous bases, adenine (A), thymine (T), guanine (G) or cytosine (C), and their respective paring A-T and G-C; panel 2, describes a nucleotide comprising a base (a), a phosphate group (c) and a ribose (b); while panel 3 demonstrates how the DNA helix is composed of complementary and antiparallel chains of nucleotides, and also illustrates how the two strands split apart and give rise to two new copies of the double-stranded DNA molecule.

Fig. 2 illustrates schematically how a combination of two inter-elemental bindings (Binding I and II) constitutes the basis of self-replication and an evolutionary process. The two elements A and B bind each other through forces receptive to cyclic temperature changes, so that the binding is created at low and broken at high temperatures (Binding I). The elements connect to form chains when oriented in a favorable geometrical position, by a binding mechanism less influenced by temperature (Binding II). A random chain of elements is created spontaneously (1), at lower temperatures the free floating elements arrange themselves along the existing chain (2), the units are bound together to form a complementary chain and a double chain is created (3), the temperature is increased and the chains depart (4), the temperature drops again and free floating elements arrange themselves along the two chains (5), two double chains are created (6), leading to that the number of chains will increase exponentially (7). New sequences occurs due to miss-incorporations (point-mutation) (7), or as a consequence of rearrangements due to double hybridizing (8) thus resulting in longer chains (9). Chains which in a given environment are more often reproduced will increase in number at the expense of other chains, and thus be selected by means of natural selection (10). This will drive the process towards chains with increasing complexity and better ability to self-replicate.

Fig. 3 illustrates the single element in the system seen from all angels, describes the design of the element.

Fig. 4 illustrates one of the possible bindings, Binding I. This binding is specific for the hydrogen bindings between complementary units (G-C, A-T) representing the respective nucleotides.

Fig. 5 illustrates the second of the possible bindings, Binding II. This binding represents the ribose-phosphate binding in the DNA molecule, which produce the nucleotide chains.

Fig. 6 illustrates that Binding I and II may be connected so that, the magnetic force in Binding I is enhanced for elements already connected by Binding II, causing that chains of the elements have greater attractive forces than free-floating elements. This will discourage mutual blocking of the free-floating elements.

Fig. 7 illustrates the facilitation of the creation of a chain when the temperature in the liquid medium is reduced and a chain is already existing.

Fig. 8 illustrates the creation of a double chained helix, due to the angle 9 (Fig. 1) on the element.

Fig. 9 illustrates separation of the two chains when the temperature of the liquid medium is increased above the T_C for Binding I.

Fig. 10 illustrates the system used to simulate a mutation wherein a different element M is designed, which is able to bind both C and T elements.

Fig. 11 illustrates a total assembly comprising a transparent water tank with a base containing electronically operated thermostats and turbulence generator, connected to a computer for operating and monitoring the temperature and turbulence in the liquid medium.

Fig. 12 illustrates independently moving elements A and B establishing Binding I (hydrogen binding between complementary units) and Binding II (representing ribose-phosphate binding in the DNA molecule). The elements are shaped as half hemispheres with four wheels (w) which are freely rotating around a central axis (a), located on the flat horizontal surface of the element which is not part of the binding structure.

Fig. 13 illustrates sectional views of the elements A and B seen from the bottom, front and top, respectively. Furthermore Binding I and II are illustrated, with a graphical illustration of the binding threshold showing the

variation of the input signal (from the input device) (i) over time and the resulting opening and closing of the switches s_1 and s_2. Further abbreviations are: m.u = motor unit w = wheels. m_1, m_2, m_3 = electromagnets. p = power supply.

As previously described self-replication is one of the hallmarks of living systems and a number of self-replicating systems or self-reproducing machines have been proposed as simulations of such systems, including the already described system by Morowitz. It is however surprising that no existing man-made system has succeeded in combining self-replication with the other essential element of living systems, i.e. adaptability.

Life on earth has evolved by means of natural selection and it is this fundamental mechanism which underlies the adaptability of biological systems. This adaptability as well as the process of self-replication can be directly traced to the structure and function of the DNA molecule. In present organisms an intricate network of interrelated biochemical reactions orchestrates self-replication of the DNA molecule. In fact one of the most powerful scientific models of biology is to view the complete organism as a vehicle set up by DNA to transfer the molecular information to the next generation of organisms. It is also widely accepted that life on earth has evolved though an early stage where simple molecular structures, probably related to the RNA molecule, replicated without the complex biochemistry of present organisms. This hypothesis is based on the fact that the RNA molecule combines the ability of replication with powerful catalytic functions. However, although the principle of self-replication and adaptability may be deduced from the structure of the DNA molecule, it has proven extremely difficult to construct artificial molecular systems which combines these two hallmarks of life, thus facilitating evolution by means of natural selection. It was thus a great surprise to the inventor when he after considerable trial and error, realized that such a system could be constructed, not from chemistry, but from carefully designed solid-phase elements, independently moving on a surface or floating freely in a liquid.

The following criteria must be met for a system to simulate an evolutionary process.

1. Reproduction: The element carrying the information must increase the probability for its own reproduction in its own environment.

2. Mutagenesis: The reproduction process must include a certain error tendency to create a repertoire of variants, which can be selected by the environment, a process referred to as natural selection.

3. Death: The system must involve recycling of the information carrying elements, such that the process is open-ended.

In order to provide such characteristics to a system based on free-floating physical elements, each element must comprise the ability to reversibly bind to each other, according to a set of rules, and in response to specific changes in the environment.

The inventor tried different alternatives for constructing such binding mechanisms, and came up with a number of possible solutions, including a combination of different systems comprising mechanical locking and mucous glues with temperature dependent adherence. Solutions comprising magnetic bindings provided however a unique way of binding since magnetic forces work across distances and involve specificity related to the positive and negative poles. The present invention may thus be combined with an electronic circuit and electromagnetic switches wherein each element is provided with a photovoltaic unit. Combined with the present invention such photoelectric arrangement also comprises a functional principle, which is not known in the prior art, e.g. Morowitz (supra), i.e. the ability to control inter-elemental bindings by changing the light surrounding the elements.

A further solution to the problem which was contemplated was the use of hard (permanent) magnetic materials. There is no obvious way by which binding between such materials are reversible in response to environmental changes, besides the fact that hard magnets become permanently inactivated when heated to extreme temperatures. The inventor found however that a combination of a hard and a soft (temporary) magnets constitutes a persisting reversible magnetic binding receptive to temperature changes in a range comprising the Curie point (T_C) of the soft magnet. This construction offers a surprisingly simple solution to the above-described problems involving materials that are commercially available and inexpensive.

There are several soft magnets with T_C ranging from 10°C to 40°C, such as Fe-Ni alloys, amorphous alloys and soft ferrites, making it possible to select materials for breaking and reestablishing magnetic bindings by temperature fluctuations around room temperature.

Freely-floating elements that form self-replicating and evolving polymers constitutes a new and surprising invention, which can be designed to address a number of different questions related to evolution and the behavior of complex systems. However, based on the forthcoming biological revolution it is designed a model of elements behaving as «ideal nucleotides», i.e. elements which interacts according to the roles of nucleotides, but without the need for a complex biochemical machinery to catalyze these interactions.

To simulate the characteristics of nucleotides and DNA/RNA molecules, a simulation of the chemical interactions between these molecules must be included. Simulation of such chemical interactions should; 1) be reversible; 2) be specific; 3) also allow some degree of unspecific binding, and; 4) the bindings must be receptive to controllable changes in the environment of the element.

According to the present invention this can be accomplished by the use of magnetic materials with different T_C, combined such that it is possible to create a system wherein specific bindings are broken at specific temperatures. By regulating the temperature it is possible to control the forces acting between the elements in the system. Thus this system is analogous to a chemical system wherein the weak hydrogen bindings are broken at low temperatures, while to break the covalent bindings increased energy supply is necessary.

The present invention thus relates to a system of self-replication polymers composed of free-floating elements, or elements moving independently on a surface, designed to interact due to their magnetic and mechanical characteristics to simulate chemical interactions and an evolutionary process, without restriction to the size of the elements

In the following two embodiments of the invention are described in detail, which however should not represent any restriction to the inventional idea. Example 1, figures 3 - 11, describes a system of self-replicating polymers represented by free floating elements interacting by temperature dependent

ferromagnetic forces. Example 2, figures 12 - 13, describes self-replication of polymeric complexes achieved by elements independently moving on a surface and interacting by electromagnetic forces.

Example 1

The element of the system are shown in Fig. 3. In one embodiment they are approximately 10 mm x 10 mm x 3 mm, made of suitable materials, such as for example plastic and with a density similar to the density of water in the temperature range from 10°C to 40°C. Each element comprises imbedded hard magnets and soft magnets in a pattern making possible bindings between only specific elements of choice.

The edge 1 of the element provides the contact surface which is exposed and wide, between two elements bound by Binding I, due to imbedded magnets below the surface. The semisylindrical surface of the edge 1 makes possible hinge like movement of the two elements, relative to each other. In one end of the edge 1 there is a cut-out 3, in the other end a tip 2 which fits into the cut-out 3 on the complementary element, causing Binding I to be directional, i.e. the elements bound points in opposite directions (Fig. 4). In one lateral edge, oriented in relation to the edge 1, there is a recess 5 with a peg 4 housing a soft magnet with T_c higher (for example 30°C) than the T_c of the soft magnets in the edge 1. The magnet imbedded in the peg 4 is concealed and/or has small contact surfaces by the recess 5 to assure that Binding II never/seldom shall occur spontaneously and to prevent that a binding shall result between the magnet in the peg 4 and the magnets imbedded in the edge 1. Contralaterally to the recess 5 is a projection 6 with a spherical head 7 containing a hard magnet to attract the magnet imbedded in the peg 4. The head 7 has a slit 8 in the extension of the projection 6 to shield the magnet to prevent Binding II occurring spontaneously and prevent binding between the magnet in the head 7 and the magnets in edge 1. The projection 6 fits into the recess 5 and when Binding II is activated the elements may rotate about an axis through projection 6. Binding II has to a certain degree a hinge function since the projection 6 may slightly top over in the recess without breaking the binding. Diagonally from the tip 2 to the projection 6 runs an axis 9 around which the element is angled. The two parts of the element thus describe the legs of an angle of 36°. The recess 5 and the projection 6 are thus oriented in different planes and a double chain of elements will create a

helix comprising 2 x 10 units in each rotation. This angled surface of the element facilitates further that the extension of a chain preferably occurs in the end of the chain carrying a recess 5, which simulates that the DNA synthesis occurs from the 3' end.

Fig. 4 illustrates Binding I and the pattern of hard and soft magnets to make possible that only element G links to element C and element A to T. This binding simulates H-bonds in the DNA molecules, and the G-C binding comprises 3 sets of magnets while the A-T binding comprises 2 sets of magnets, corresponding to 3 H-bonds and 2 H-bonds respectively between the bases. Accordingly the G-C binding is stronger than the A-T binding which promote the different characteristics of the different sequences of elements.

The imbedded magnets (10, 11, 12) have the following characteristics:

The magnet 10 is a hard magnet, made of for example neodymium, oriented with the positive pole towards the contact surface. Since all hard magnets are such oriented they are not attracted to each other and Binding I is specific for G-C and A-T elements respectively. Covering the positive pole of the magnet 10 is a hood 11 enveloping the outer end of the magnet and consisting of a soft magnetic material, made of for example a amorphous alloy, with T_C in the temperature range, for example approximately 25°C, in which Binding I is broken. This hood 11 mediates the magnetic forces from the hard magnet 10 to the contact surface 1 of the element (Fig. 3) only when the temperature is below T_C. When the temperature is above T_C the contact surface 1 is demagnetized. The soft magnet 12 is made of the same material as the hood 11 and has a $T_C = 25°C$. The localization is designed to interact with the magnetic forces of the hard magnet located in the opposite position in the complementary element. The demagnetization of the soft magnet 12 at temperatures above approximately 25°C promotes breaking of Binding I.

Fig. 5 illustrates Binding II, which simulates the ribose-phosphate binding in the DNA molecule producing the nucleotide chains. Binding II is maintained by the hard magnet 13, e.g. made of the same material as magnet 10, oriented with the positive pole towards the slit 8. This magnet is covered with the hood 14, made of a soft magnetic material with a T_C higher than for the soft magnets in Binding I, say 30°C, (Fig. 3). Magnet 13 is magnetizing the soft

magnet 15 located in the peg 4 in the complementary element. The soft magnet 15 is made of similar material as the hood 14, with $T_c = 30°C$. Thus Binding II is maintained at temperatures below 30°C. The different demagnetizing temperatures for Binding I and II makes the last more resistant to higher temperatures. When the ambient temperature cycle around 25°C only Binding I will be affected. Binding II breaks only when the ambient temperature is increased above 30°C.

Binding II allows the elements to rotate around the projection 6 (Fig. 3). Furthermore the direction of the slit 8 makes possible movement of the bound elements in a plane through the projection 6 (Fig. 1), vertically on the figure plane (Fig. 3). The described mobility of Binding II may lead to several secondary structures which will produce different characteristics, since structure and function are interrelated.

Since Binding II is made by magnets protected by the slit 8 and the recess 5, this binding will never/seldom come into being spontaneously between free-floating elements.

Fig. 6 describes an embodiment of the invention wherein the elements are modified such that the magnetic forces in Binding I are enhanced when Binding II is activated.

The elements of this embodiment comprise the magnets 10, 11, 12, 13 and 14 described above. In addition each element contains a bridge comprising a soft magnet 16, with $T_c = 30°C$, located inside the peg 4 and in contact with another soft magnet 17, with $T_c = 25°C$, which ends at the contact surface 1 for Binding I between the magnets 10 and 12, opposite to an additional soft magnet 18 in the complementary element.

This arrangement will make Binding I stronger when the temperature is below 25°C which is the temperature at which Binding I is broken. In this embodiment the elements already united in chains will exercise greater attractive forces than free-floating elements, and will thus reduce the trend that free-floating elements are blocking each other.

Figure 7 illustrates that an existing chain will spontaneously facilitate the creation of complementary chains when the ambient temperature cycles above and below the T_c for Binding I. Thus when the temperature is lowered

the elements already chained together will attract free floating complementary elements and bind them via Binding I. This binding will then function as a hinge in that the newly bound elements will move back and forth around an axis through the contact surfaces 1, and cause that elements in juxtaposition will be geometrically in good position for spontaneously creation of Binding II, thus producing a new chain.

Figure 8 illustrates the creation of the helix structure of the double chain, due to the angle 9 of the surface of the element, thus simulating the DNA helix structure.

Figure 9 illustrates use of the system according to the invention to simulate denaturation of the DNA molecule by increasing the temperature. In the system according to the invention increasing the ambient temperature above the T_C for Binding I will break the binding, and the two chains will separate.

Figure 10 illustrates how the invention can simulate creation of a mutation. Mutagenes are agents inducing exchange of bases in the DNA molecule and can be for example chemicals changing the characteristics of the bases abolishing their ability to code specifically. In the system of the present invention an element M is constructed, which due to the pattern of magnets can bind (Binding I) to both the C element and T element.

Furthermore it is possible to construct mutagenic elements with a defect in the ability to create Binding II. This will result in shorter chains.

The system according to the invention can also be designed to simulate a primitive translation process wherein the genetic information in the DNA molecule is translated to chains of amino acids. In present organisms this process is performed by complex biochemical mechanisms involving cellular organelles called ribozomes. Resent findings suggest however that the evolutionary basis of this process be related to direct affinity between different amino acids and specific triplets or codons of nucleotides. The combination G-C-A in a chain of nucleic acids may e.g. attract the amino acid alanine. An exciting nucleotide chain may thus promote chains of amino acids in a similar manner as complementary strands are created.

In the present system an element Aa simulating an amino acid is designed to bind to the contact surface 1 of three specific elements of the simulated DNA

chain, with which the following creating of a binding (corresponding to Binding II) for creating a chain of amino acids to simulate a peptide or protein. By varying the pattern of magnets imbedded in the contact surface 1 of the Aa elements, different amino acids, binding to different codons of elements are designed.

Still further embodiments of the invention may comprise elements simulating biological co-factors with the ability to interfere with or facilitate binding of specific elements.

In other embodiments the magnetic forces in the elements can be produced by electromagnets powered by small photovoltaic units on each element. In this case the evolutionary process is powered by changes in the electromagnetic radiation instead of water temperature. These two mechanisms may also be combined.

Figure 11 illustrates a container for liquid, such as water, with transparent wall for example 150 cm tall and 65 cm in diameter, containing 500 l of liquid. The container has a base with an electronically operated thermostat and turbulence generator, connected to a programmable unit for regulation of liquid temperature and turbulence, for example a computer.

Simulation of self-replication and mutation

1. As a start situation a large number of different elements, such as 2500 of each of the four types, are floating freely in the liquid such as water of the container (Fig. 11), and the temperature of the liquid is between T_c for Binding I and II, such as 28°C.

2. The first chain can be created
   a) spontaneously via Binding II, which has been designed to be a slow process due to the location of the magnets 13, 14 and 15, or
   b) by constructing a chain of elements and add this chain to the container.

3. A new chain is then created by lowering the water temperature below the T_c for Binding I, such as for example 20°C. Free elements will bind to complementary elements (G-C, A-T) in the template chain, and neighboring elements will be connected by Binding II as described above, simulating

elongation of the chain. When the chain is elongated the total binding becomes stronger since an increasing member of magnetic bindings are holding the chains together.

The result is creation of a simulated DNA helix.

Chain reaction: To facilitate a chain reaction it will be necessary to let the water temperature cycle between for example 20°C and 28°C, i.e. below and above the T_c for Binding I. New chains will then be created as described above and when Binding I is broken by increasing the temperature the number of template chains are doubled. This results in an exponential increase of the number of chains in the container.

Recirculation or death: A chain will dissolve if the water temperature is increased above the T_c for Binding II. Balanced or specific death of certain chains can be obtained by regulating temperature and turbulence in such a way that short pulses of water with a specific temperature hit a group of chains.

Mutations: Point mutations will appear spontaneously by incorporation of different mutagenic elements in the chains. These mutagenes can be of the type suggested in Fig. 10, wherein Binding I is affected or a type wherein Binding II is affected (not shown).

Mechanical stress, deficient Binding II or high temperature will produce shorter chains, while longer chains can be produces when one chain binds two other chains (double hybridization) (Fig. 2) or because Binding II occurs spontaneously. A chain of 10 elements can be varied $4^{10} = 10^6$ different ways while a length of 20 elements gives 10^{12} possible combinations. If one new chain of 20 elements is produced every minute, testing of all combination will require 2×10^6 years.

Natural selection

Mutants, which for any reason are more reproducible, will increase in number at the expense of others. Such advantageous characteristics can be;

- Secondary structures stabilizing the chain such that it is resistant to breaking when the temperature is increased,

- secondary structures inhibiting the replication of other chains (simulating natural ribozymes),

- secondary structures «taking advantage» of other elements in the solution,

- sequences adapted to the distribution of freely flowing elements, and

- chains cooperating with other chains.

The direction of the evolutionary process will be modified by the environment in the container (temperature and turbulence profile, concentration of elements, presence of other chains and elements). The selection process will drive the system towards better replication rates and increasing complexity.

Example 2

Elements moving on a surface.

Self-replication of polymeric complexes is also achieved through elements moving on a surface. One design of such a system involves self-propelled elements on wheels moving in chaotic patterns, and connecting by Binding I and Binding II through electromagnetic forces. A detailed embodiment is presented in Figure 12 and 13.

The motor unit (m.u.) with 4 wheels (w) has free rotation around a central axis (a) and is programmed to move the element in a chaotic pattern. The motor unit is powered by an independent power supply, or by the power supply (p) providing the electromagnets (m_1 and m_3) (Fig. 13).

There are two different types of elements (A and B), which form complementary pairs through Binding I. This specific binding occurs because of opposite charge in the central electromagnet (m_1), which is oriented perpendicular to the underlying surface. Additional pairs of elements (e.g. A-T and G-C, corresponding to the nucleotides) increase the complexity of the system. Such specific pairing between several elements may be achieved by combinations of positive and negative magnets in Binding I, or by differentiating the profile of the surface of the binding.

The elements (A or B) are joined together in strands/polymers by Binding II. This binding occurs between the electromagnet (m_2) and the soft/temporary magnet (m_3), which are positioned to meet in the horizontal orientation. The activated electromagnet (m_2) pulls on the soft/temporary magnet (m_3) to form a hinge between the connected elements

Binding I is designed to occur spontaneously between independently moving elements, while Binding II is designed to rarely occur spontaneously between independently moving elements. However, Binding II is designed to occur spontaneously between elements connected by Binding I to elements already connected by Binding II.

The electromagnets (m_1 and m_2) are powered by the power supply (p), which may e.g. be an electrolytic battery, a fuel cell, or a photovoltaic unit.

The magnetic forces of Binding I and Binding II is regulated by the switches (s_1) and (s_2), respectively. These switches are themselves regulated by the in-put device (i), which may e.g. be a radio receiver, a heat or light sensor, or a timer. (s_2) is set to open more rarely than (s_1), thereby making Binding II more stabile than Binding I. In one design (s_1) is sensitive to cyclic changes in light intensity (e.g. day and night), while (s_2) only opens in response to light intensities above these cyclic changes. An example of this relationship between the switches (s_1) and (s_2) and a cyclic in-put variable of (i) is illustrated in the binding threshold graph (Fig. 13).

Applications

The system according to the present invention has several areas of application.

Education: The system is, as demonstrated above, able to simulate the fundamental characteristics of life in a manner that is easily understandable by children and adults. The system mediates biologically and evolutionary knowledge and can be used as educational tools for general and molecular biology. It can furthermore be combined with a computer based multimedia educational system, suitable for different age groups and competence levels. The programmable unit according to the invention (Fig. 11) can be used with suitable software and hardware to develop programmable temperature and

turbulence profiles favoring different type of chains and thereby guide the evolutionary process in different directions, protocol the development of old and new chains and map the characteristics of different chains, for example possible secondary structures.

Games: An evolutionary system comprise a form of «life» and the challenge will be to «breed» new and steadily more robust and complex «species» of this form of life, by playing with the environment (temperature, turbulence, additional elements) to increase the probability for the creation and well being of certain chains. The challenge is then stepped up to a higher level by placing the above-created chain in a container with another sequence. The two sequences are then parts of each other's environment, which may lead the evolutionary process in new directions. Some sequences may be destroyed in the competition while other may cooperate on the replication process.

By using electronic communication applications, e.g. the Internet, various sequences and their characteristics may be exchanged and the evolutionary process has expanded beyond its own container.

The challenge of this game will be to produce sequences, which compete with other under varying conditions. The sequences may be named and made known via Internet.

Scientific tool: This invention represents an artificial replication system comprising the ability to evolution by means of natural selection, and will as such represent an independent scientific achievement. Furthermore, the invention constitute a new and unique tool for simulating and investigating the behavior of complex systems, particularly related to the characteristics of self-replication and natural selection. Additionally, the specific hybridization between polymers may be applied as means for calculation, an application that has been extensively demonstrated for nucleic acids (DNA computing).

Sculpture, decoration and exhibitions: The system according to the present inventions has dynamic characteristics, which may be visually appealing. Thus it is possible to use the system to create new and visually appealing physical structures, not only in the form of helical structures resembling the DNA molecule. Furthermore a reproducible system for swimming pools, can be designed for decoration purposes and/or as toys.

CLAIMS

1. System of independently moving elements which can form self-replicating polymeric complexes through reversible inter-elemental binding structures which are established and broken in response to changes in the environment of the individual binding,
c h a r a c t e r i z e d i n that the inter-elemental binding structure comprises a combination of the element's physical shape and mechanical, ferromagnetic, or electromagnetic binding mechanisms, which are reversible in response to ferromagnetic, electromagnetic, kinetic or thermal alterations in the environment of the individual binding.

2. System according to claim 1,
c h a r a c t e r i z e d i n that the binding structure of the element is complementary to the binding structure of other specific types of elements according to the physical design and means of adhesion.

3. System according to claims 1,
c h a r a c t e r i z e d i n that the binding structure of the element is complementary to the binding structure of several types of elements according to the physical design and means of adhesion.

4. System according to claims 1 - 3,
c h a r a c t e r i z e d i n that the binding structure of the element is complementary to binding structures on other elements, thereby allowing pairing of elements.

5. System according to claims 1 - 4,
c h a r a c t e r i z e d i n that the binding structure of the element is complementary to binding structures on the same element, thereby allowing polymerization of elements.

6. System according to claims 1 - 5,
c h a r a c t e r i z e d i n that the binding structures of the element are pairing (Binding I) and polymeric (Binding II).

7. System according to claims 1 - 6,
c h a r a c t e r i z e d i n that the element structure of Binding I has

exposed and/or wide contact surfaces, thereby allowing the binding to occur readily between individually moving elements.

8. System according to claims 1 - 7,
characterized in that the element structure of Binding II has concealed and/or small contact surfaces, thereby restricting the binding to occur rarely between individually moving elements.

9. System according to claims 1 - 8,
characterized in that Binding I and Binding II has a specific geometric relationship in which elements connected by Binding I to elements already connected by Binding II, are oriented such that the binding structures of Binding II are aligned, thereby allowing elements connected by Binding II to facilitate Binding II between elements connected by Binding I.

10. System according to claims 1 - 8,
characterized in that Binding II is more stable than Binding I.

11. System according to claim 1 - 10,
characterized in that the inter-elemental bindings involve materials with different Curie points (Tc) such that specific bindings are responsive to specific changes in temperature.

12. System according to claim 1 - 11,
characterized in that the inter-elemental bindings involve electromagnets regulated through electronic circuits.

13. System according to claim 1 - 12,
characterized in that the inter-elemental bindings involve mechanical locking systems responding to mechanical forces.

14. System according to claim 1 - 13,
characterized in that the inter-elemental bindings involve combinations of ferromagnetic, electromagnetic, and/or mechanical mechanisms..

15. System according to claim 1 - 14,
characterized in that the elements comprise a power supply, e.g. an electrolytic battery, a fuel cell, or a photovoltaic unit.

16. System according to claim 1 - 15,
characterized in that the elements comprise a self-propelling motor unit.

17. System according to claim 1 - 16,
characterized in that the inter-elemental bindings are connected to a regulatory device e.g. a radio receiver, a heat or light sensor or a timer.

18. System according to claims 1 - 17,
characterized in that the characteristics of the bindings, are in addition to the magnetic forces, related to the size and shape of the contact surface between the elements, preferably that the complementary contact surface (1) for Binding I is semicylindrical and for Binding II is a projection (6) with a slit (8) spherical head (7), and a recess (5) with a peg (4) in the bottom respectively, and the elements have a tip (2) in one end of the surface (1) and a cut-out (3) in the other end, making Binding I directional.

19. System according to claim 1 - 18,
characterized in that the semicylindrical contact surface (1) for Binding I there is imbedded at least one hard magnet (10) with the positive pole directed towards the contact surface (1) and coated with a soft magnet (12), and in the contact surfaces (4, 7) for Binding II are imbedded one hard magnet with the positive pole directed towards the contact surface (13) coated by a soft magnet (14) and a soft magnet (5).

20. System according to claims 1 - 19,
characterized in that the Tc for the soft magnet in the contact surfaces of Binding I is lower than for the soft magnet in the contact surfaces of Binding II, preferably that Tc of Binding I is 25°C and Tc of Binding II is 30°C.

21. System according to claims 1 - 20,
characterized in that the elements according to the pattern of magnets in Binding I are separated into A, C, G and T elements such that element A only can bind to T, and element C only can bind to G, or into mutagenic elements (M) which can bind to more than one element.

22. System according to claims 1 - 21,
characterized in that the said element is V shaped along a line (9)

running diagonally from the tip (2) to the projection (6) wherein the angle between the two surfaces thus created is 36°.

23. System according to claims 1 - 22, characterized in that further elements have imbedded adjacently localized soft magnets (16, 17) comprising materials with two different Tc, running from the contact surface (4) of Binding II to the contact surface (1) of Binding I, preferably Tc for the soft magnet (16) closest to contact surface (4) is 30°C Tc and for the soft magnet (17) closest to the contact surface (1) is 25°C.

24. System according to claims 1 - 23, characterized in that the hard magnet is neodymium, alnico and ferrites and the soft magnet is a Fe-Ni-alloy, amorphous alloy and soft ferrites, preferably an amorphous alloy.

25. System according to claims 1 - 24, characterized in that the elements have densities close to the density of water.

26. System according to claims 1 - 25, characterized in that the elements are floating in a transparent water-filled container.

27. System according to claims 1 - 17, characterized in that the elements are mobile on a surface.

28. System according to claims 1 - 27, characterized in that the environment of the elements can be manually or electronically controlled, preferably that the control device is connected to an electronic communication network, e.g. the Internet.

29. Use of the system according to claims 1 - 28 wherein creation and replication of DNA molecules is simulated.

30. Use of the system according to claims 1 - 29 to simulate evolution by means of natural selection.

31. Use of the system according to claims 1 - 30 as a device for education, entertainment, decoration, scientific, and computational purposes.

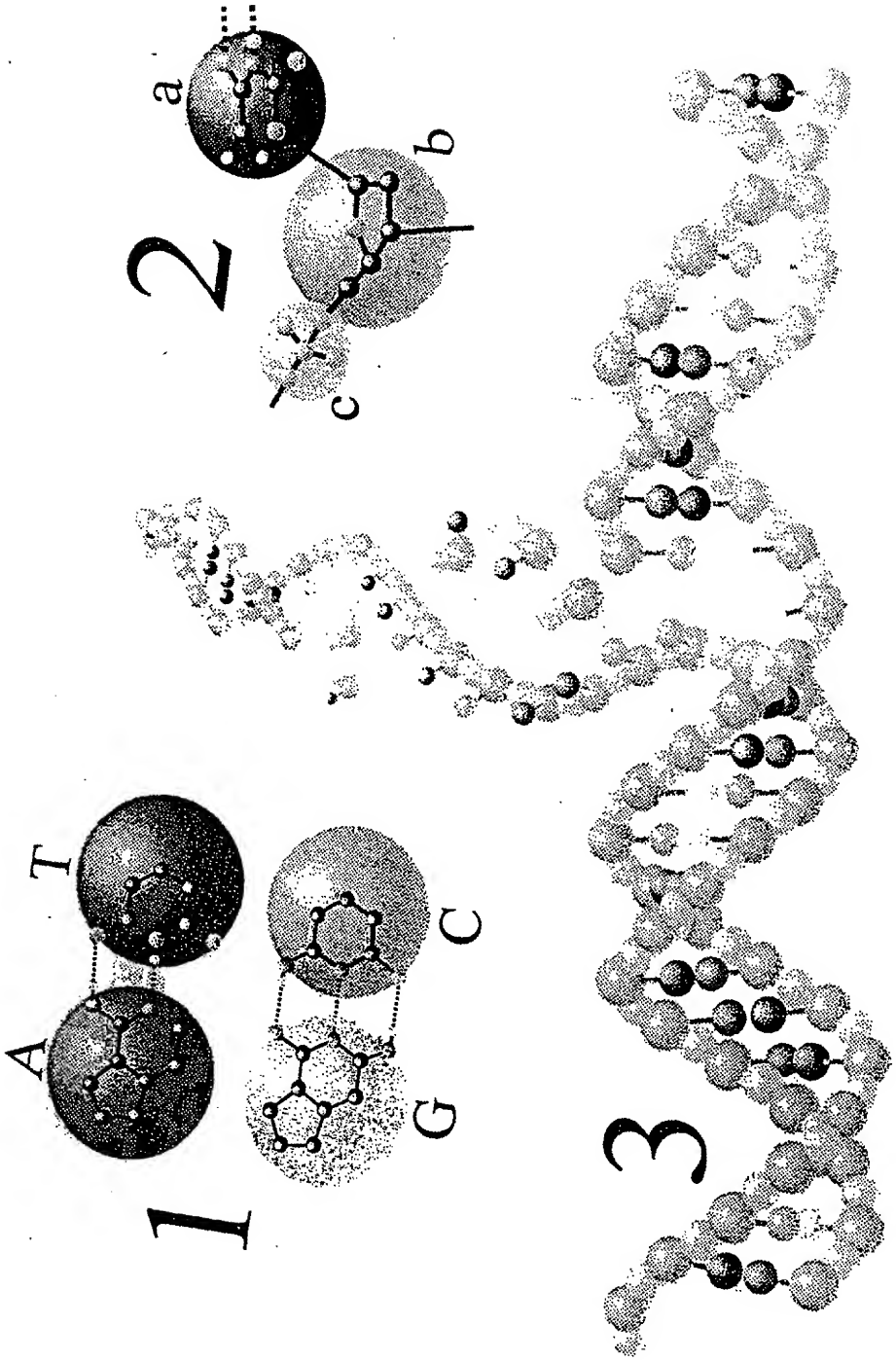


FIG 1

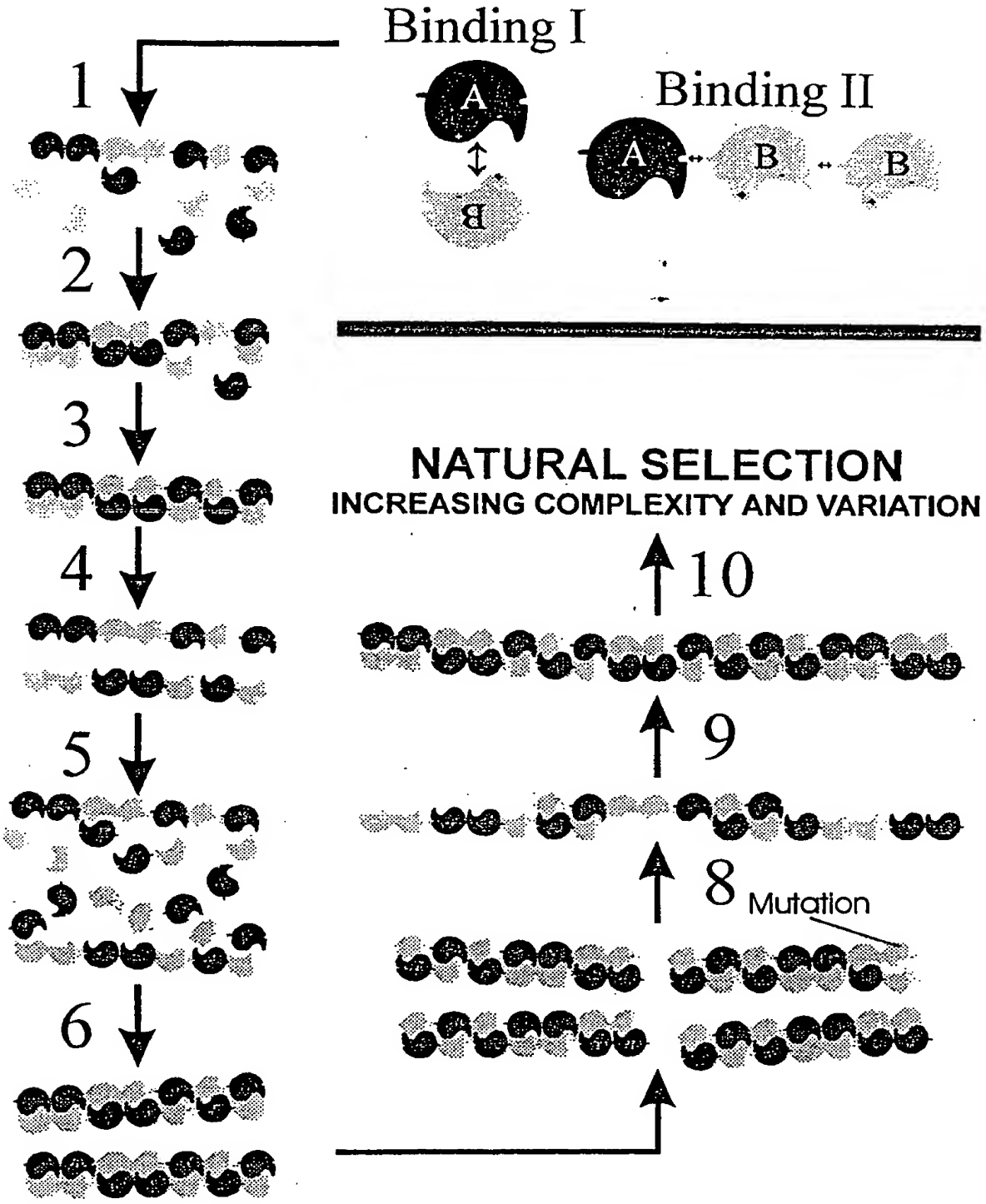

Binding I
A
B
Binding II
A
B
B
1
2
3
4
5
6
NATURAL SELECTION
INCREASING COMPLEXITY AND VARIATION
10
9
8
Mutation

FIG 2

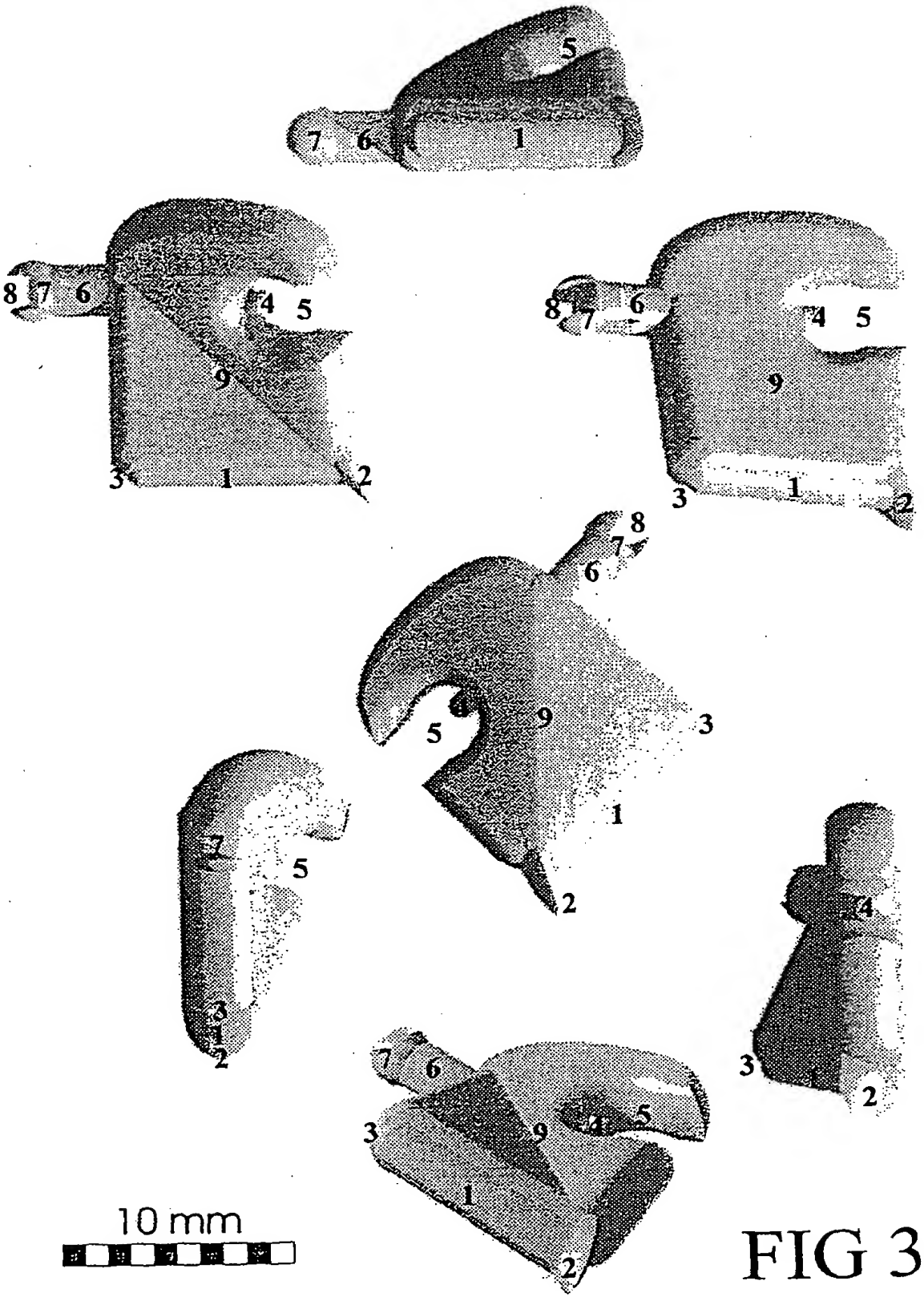


FIG 3

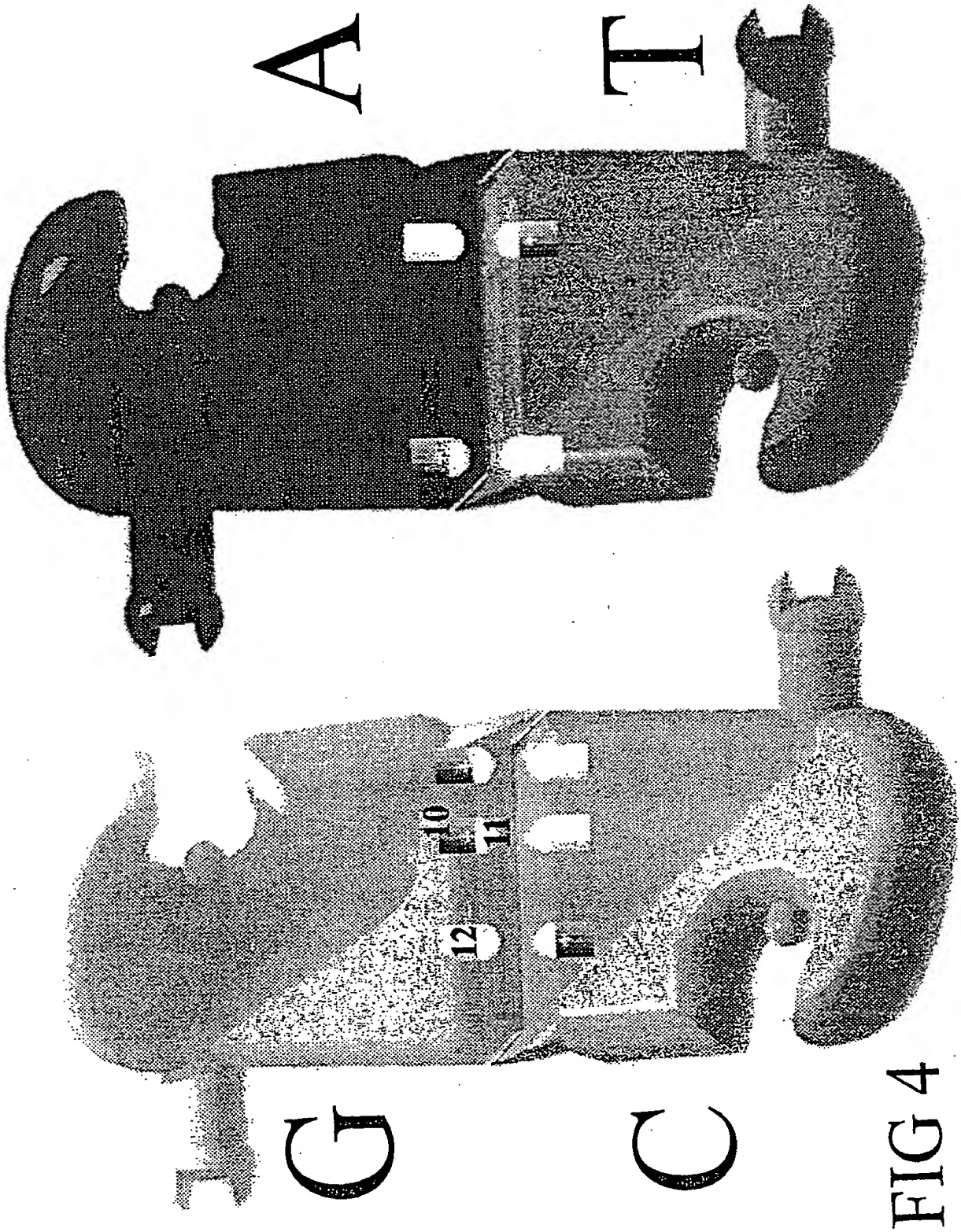


FIG 4

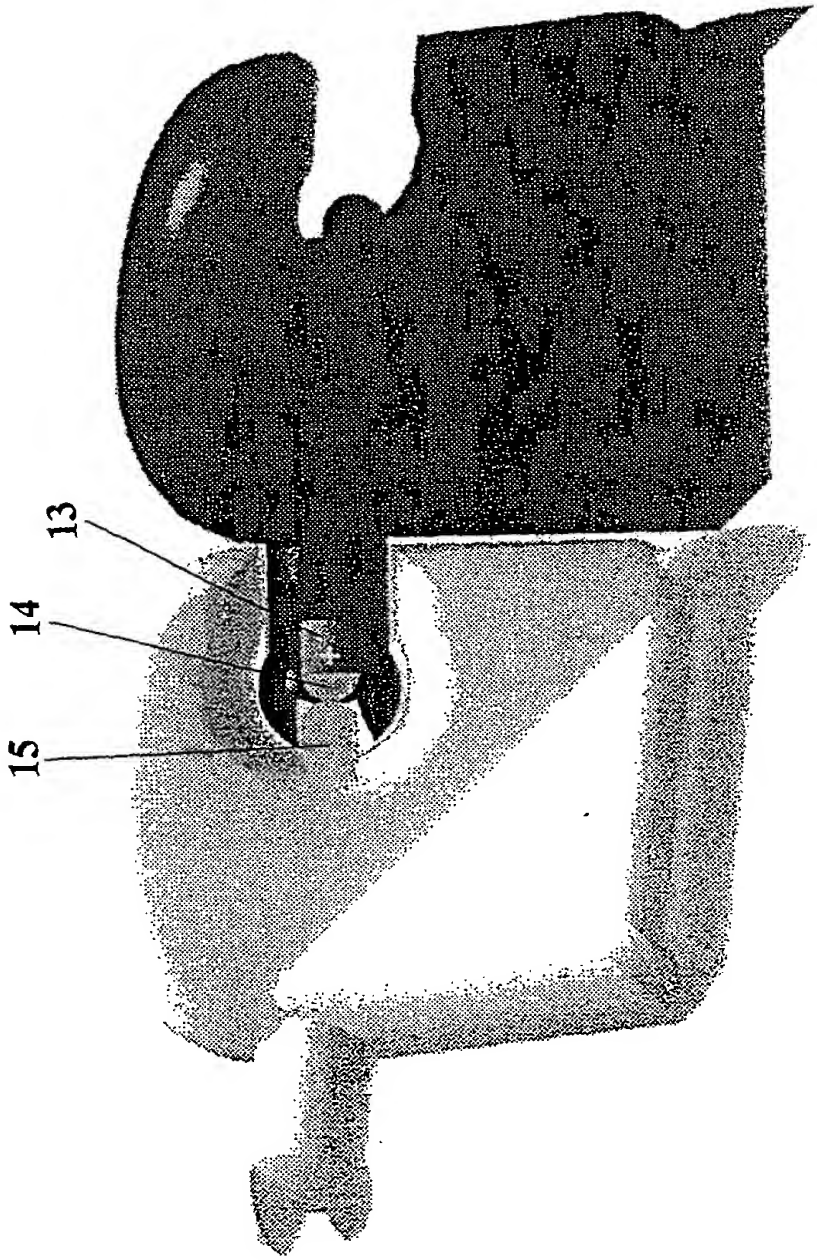


FIG 5

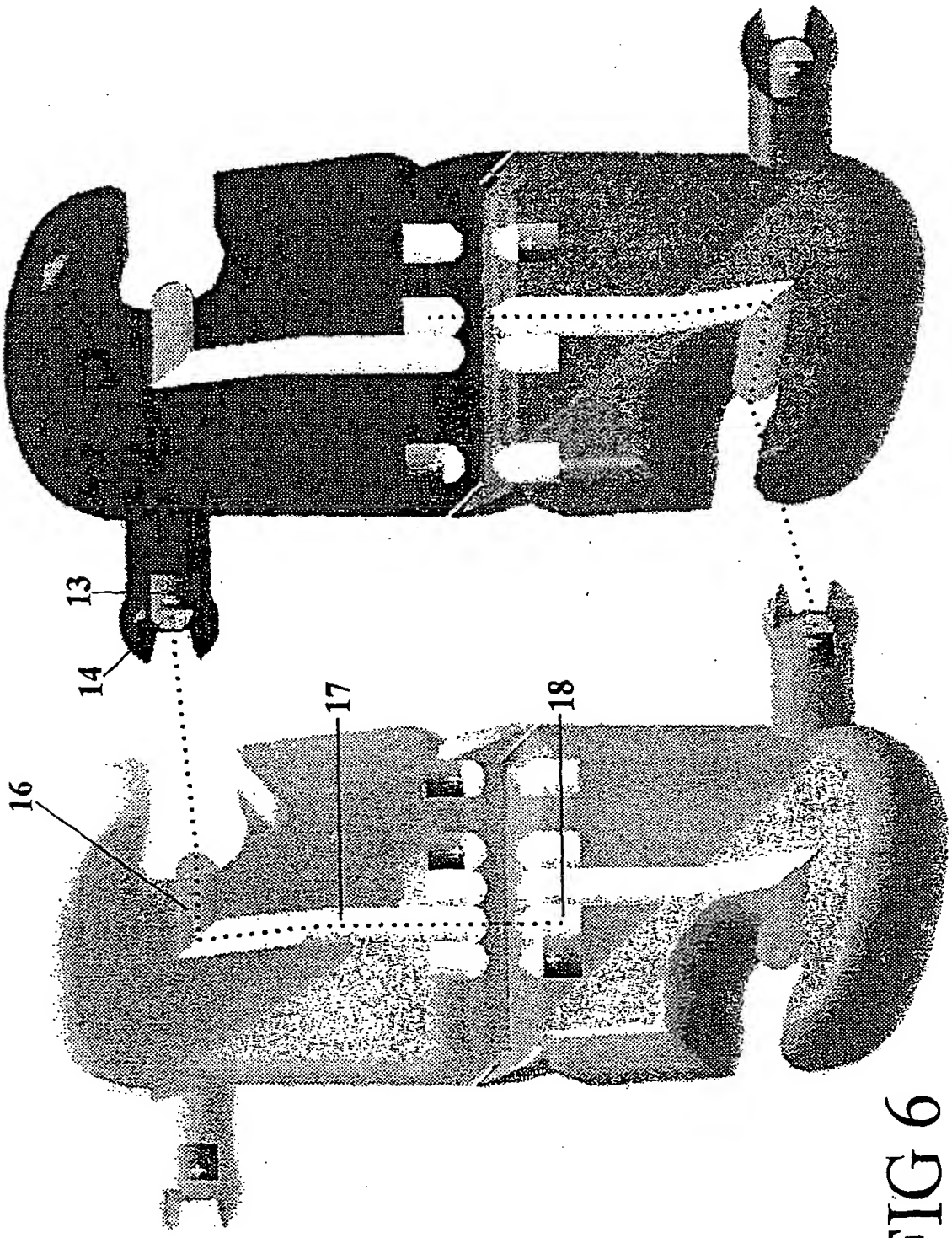


FIG 6

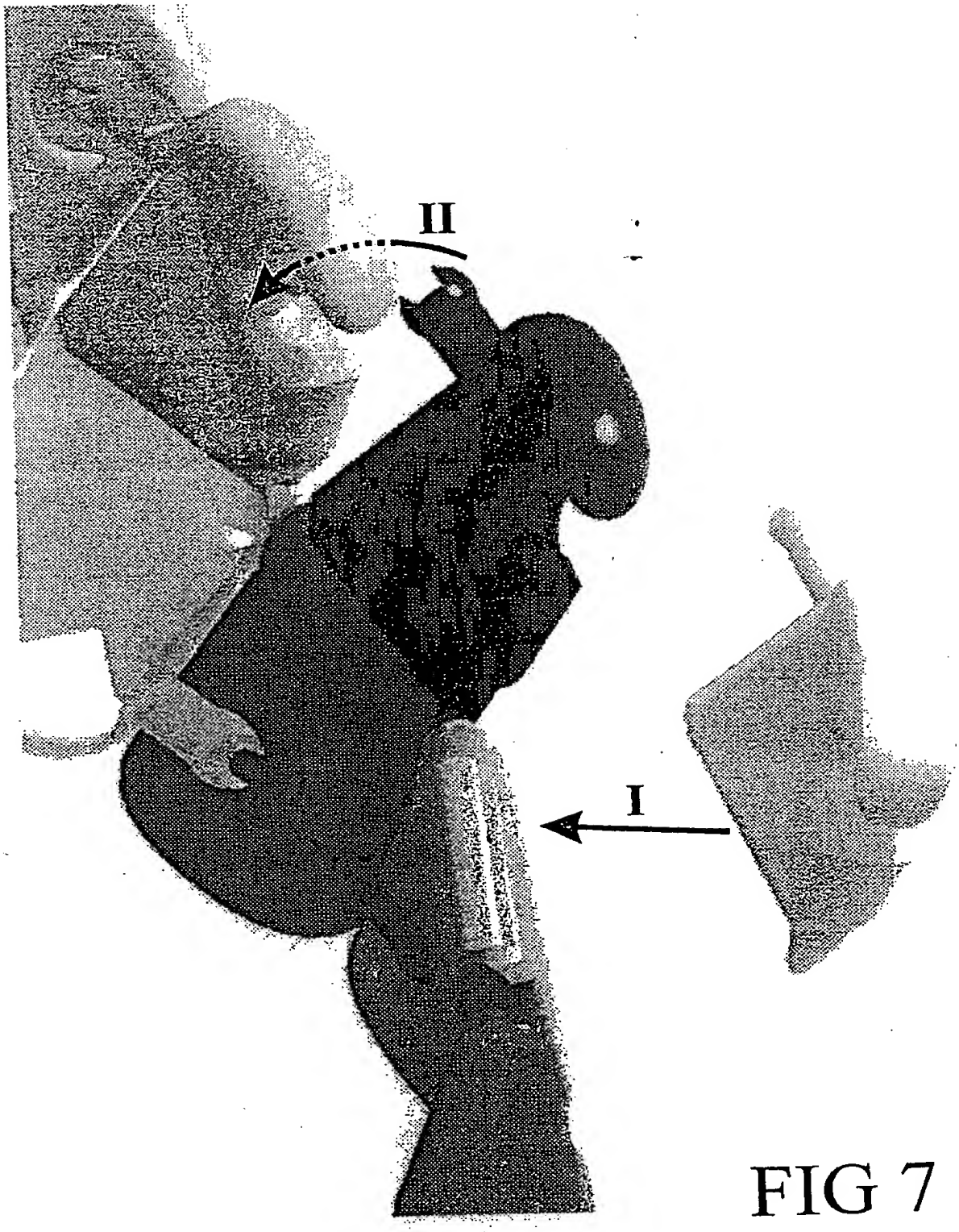


FIG 7

FIG 8

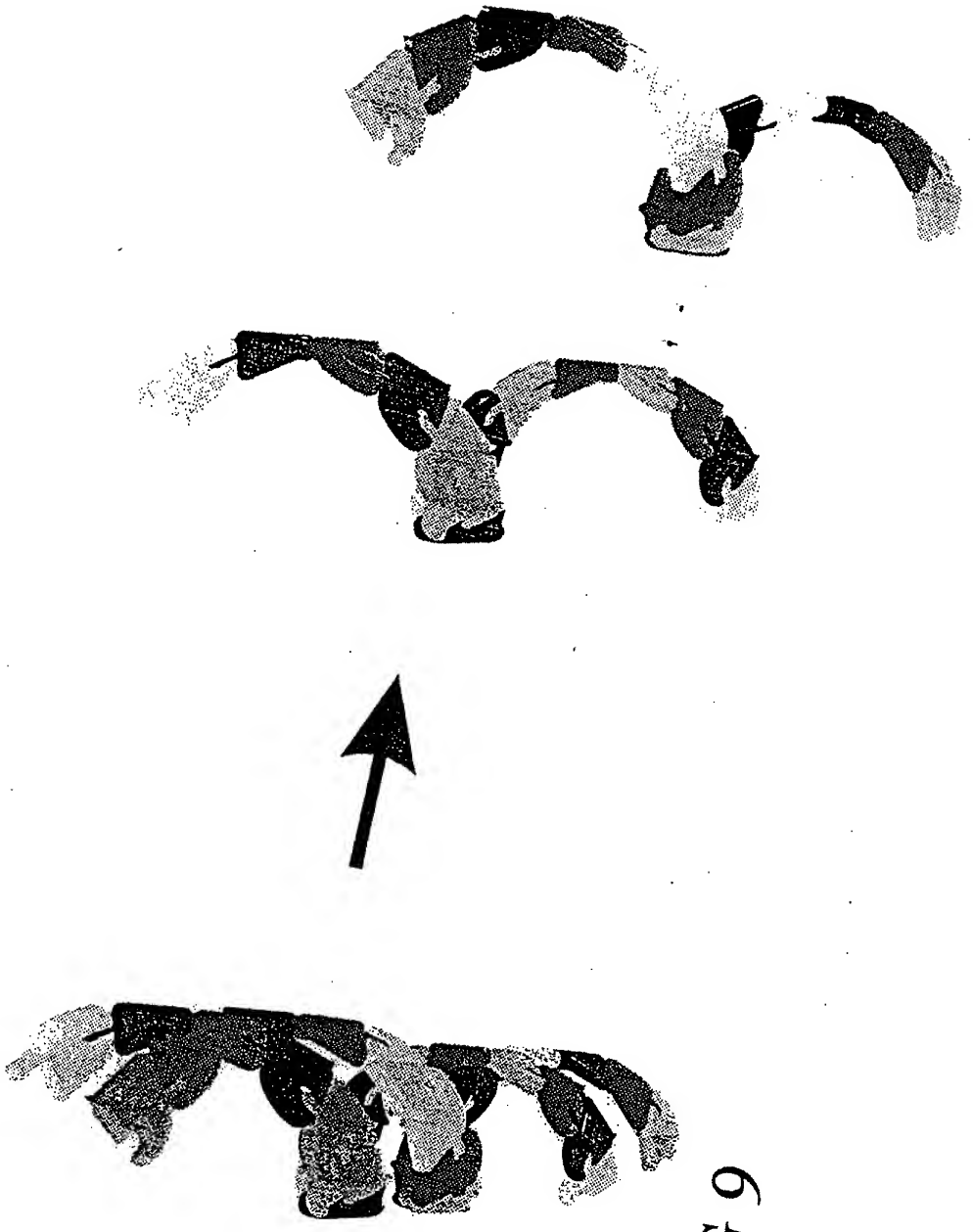


FIG 9

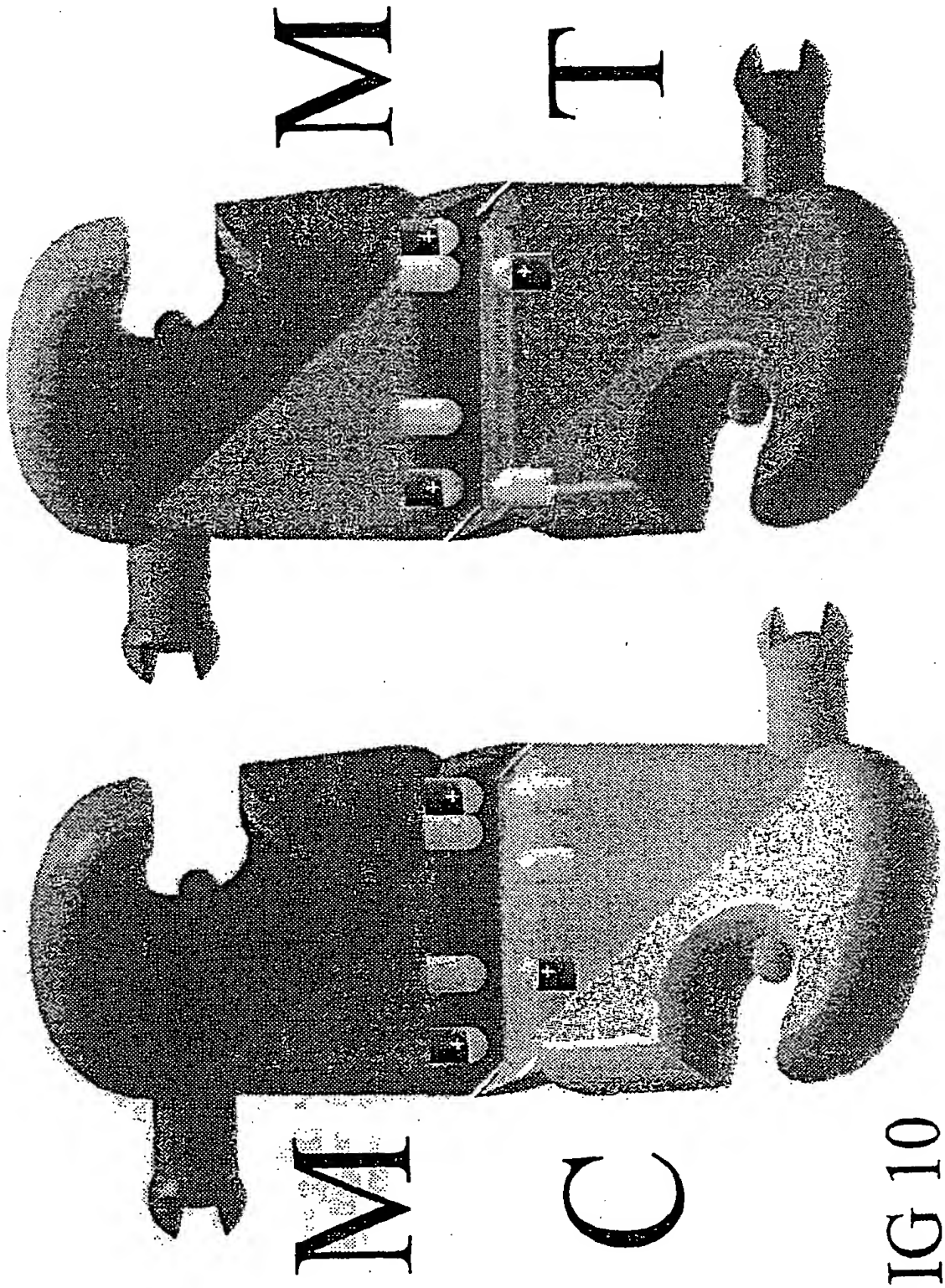
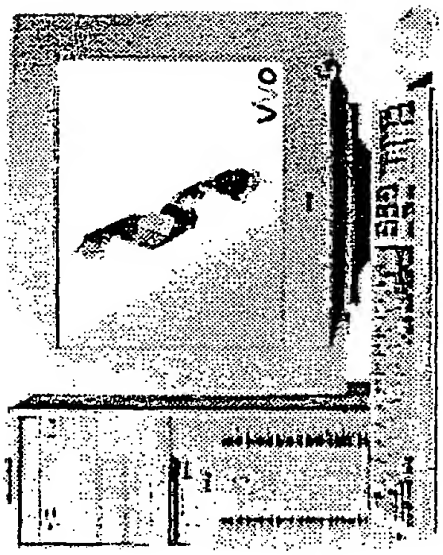


FIG 10



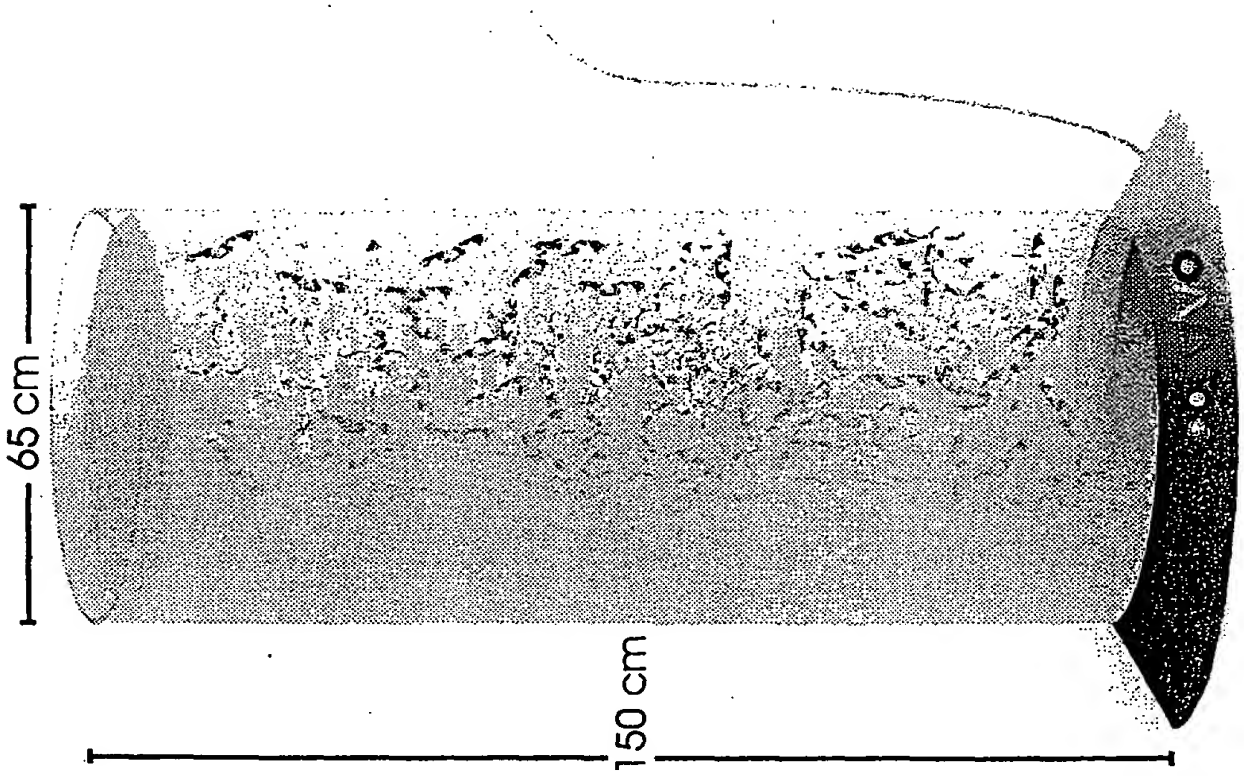


FIG 11

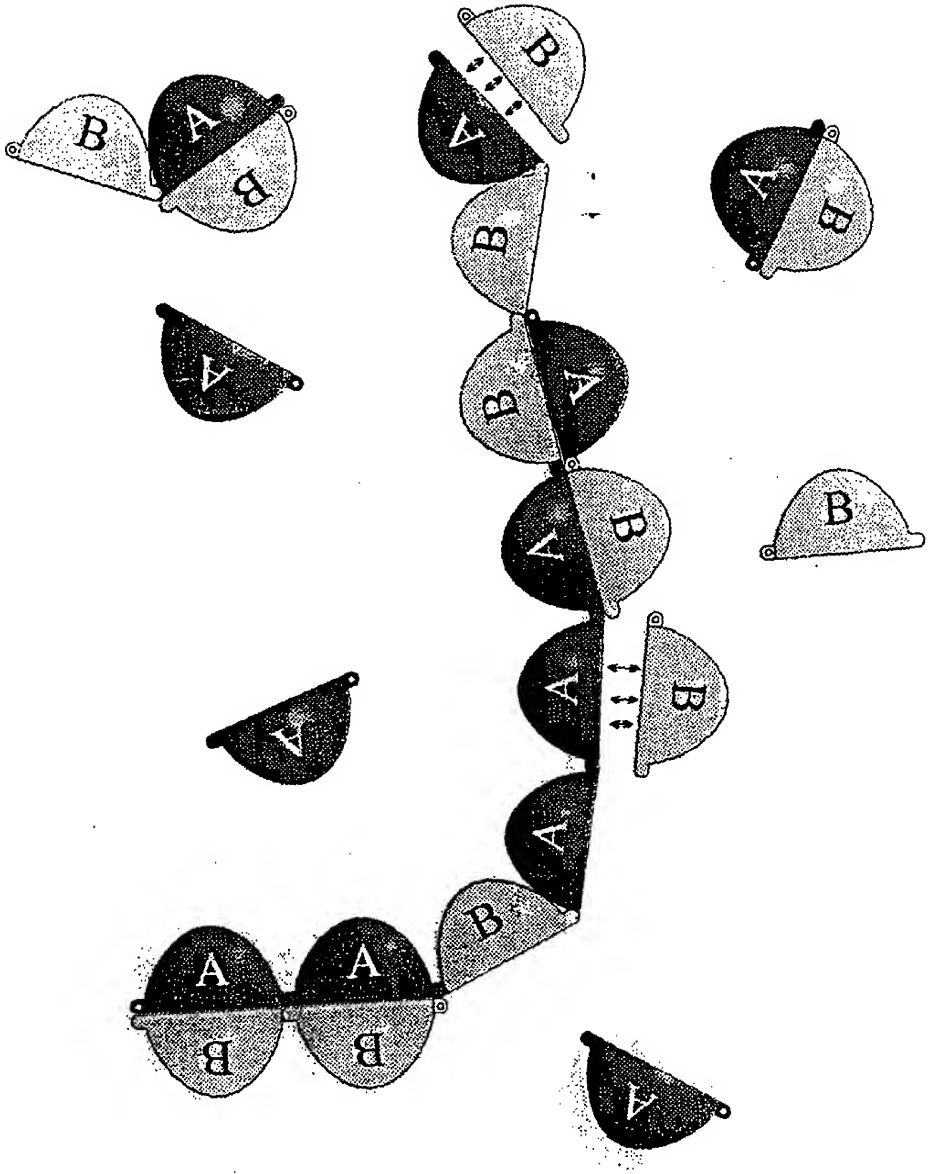
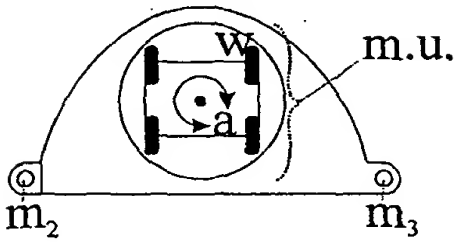
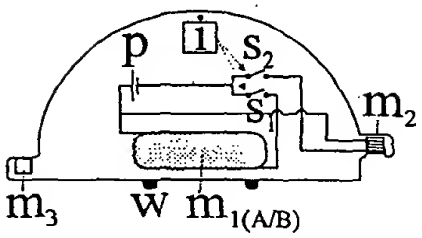


FIG 12

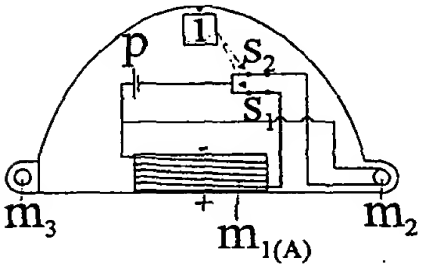
BOTTOM VIEW
(A/B)



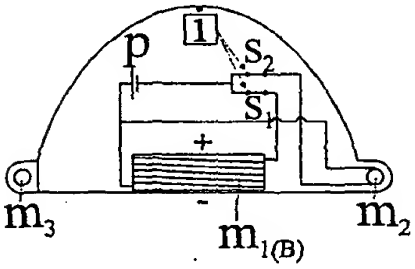
FRONT VIEW
(A/B)



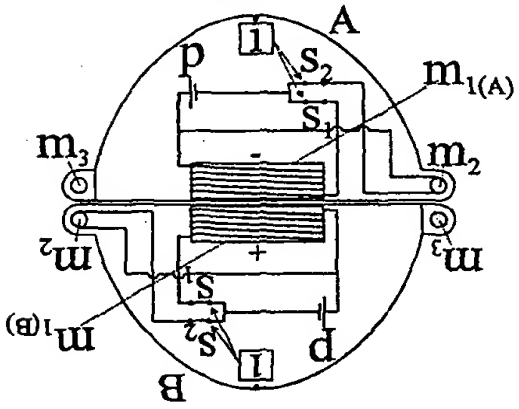
TOP VIEW (A)



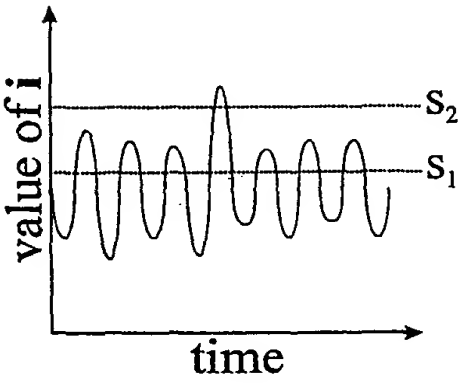
TOP VIEW (B)



BINDING I
(TOP VIEW)



BINDING
THRESHOLD



BINDING II
(FRONT VIEW)

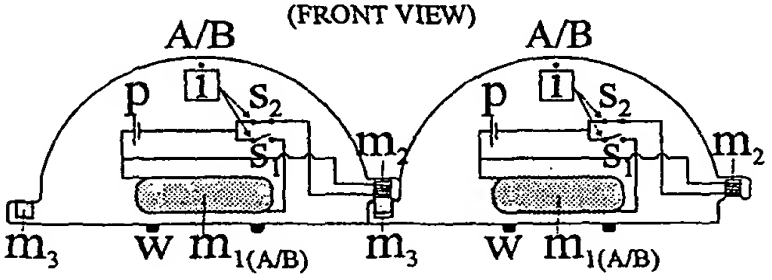


FIG 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 99/00334

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G09B 23/26 // G09B 23/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 3502968 A1 (KARFUNKEL, H.), 31 July 1986 (31.07.86), the whole document ---	1-10,13,14, 18,25,26, 29-31
A	Derwent's abstract, No P8316 E/45, week 8245, ABSTRACT OF SU, 896675 (AS UKR PHYS MECH IN), 7 January 1982 (07.01.82), the whole document ---	1-31
A	Amerikan Scientist, Volume 47, 1959, HAROLD J. MOROWITZ, "A model of reproduction" page 261 - page 263 --- --------	1-31

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 March 2000	04.04.00

Name and mailing address of the International Searching Authority
European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk

Authorized officer
Johan L"fstedt / MR

INTERNATIONAL SEARCH REPORT

Information on patent family members

02/12/99

International application No.
PCT/NO 99/00334

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3502968 A1	31/07/86	NONE	